Survey Results of Green Sea Urchin (Strongylocentrotus droebachiensis) Populations in Queen Charlotte Strait, British Columbia, November, 1998, 1999, 2000, 2001 and October, 2002

B.J. Waddell and R.I. Perry

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
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SURVEY RESULTS OF GREEN SEA URCHIN (*Strongylocentrotus droebachiensis*) POPULATIONS IN QUEEN CHARLOTTE STRAIT, BRITISH COLUMBIA, NOVEMBER, 1998, 1999, 2000, 2001 AND OCTOBER, 2002

by

B.J. Waddell and R.I. Perry

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

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ABSTRACT

Waddell, B. J., and Perry, R. I. 2005. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, November, 1998, 1999, 2000, 2001 and October, 2002. Can. Tech. Rep. Fish. Aquat. Sci. 2591: xiii + 150 p.

Five surveys of green sea urchins (*Strongylocentrotus droebachiensis*) were undertaken jointly between Fisheries and Oceans Canada (DFO) and industry (West Coast Green Urchin Association - WCGUA) in Queen Charlotte Strait, British Columbia, every fall from 1998 to 2002. These surveys are part of a continuing series, where long-term objectives are to assess variability in green sea urchin populations, and to monitor impacts due to a commercial fishery. The surveys described here were all performed prior to the opening of the commercial green sea urchin fishing season, and were undertaken at three sites, which included areas open or closed to commercial fishing. Surveys were conducted by SCUBA divers, using the transect-quadrat method. Data were collected on size and abundance of green sea urchins, gonad weight and quality, and on the depth, substrate and vegetation; results are presented for three size classes.

The density and biomass of legal-sized green urchins at the Stephenson Islets have fluctuated but have generally increased over the survey period, despite the fact that this location has been commercially fished each year. The densities and biomasses of legal-sized green urchins at the non-fished locations have also generally increased over the five year survey period. A large successful spawn appears to have occurred in 1998, and a second, but less abundant spawn followed in 1999. The densities and biomasses of sublegal-immature (new recruits) green urchins decreased during the 2000, 2001 and 2002 annual surveys.

RÉSUMÉ

Waddell, B. J., and Perry, R. I. 2005. Survey results of green sea urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British Columbia, November, 1998, 1999, 2000, 2001 and October, 2002. Can. Tech. Rep. Fish. Aquat. Sci. 2591: xiii + 150 p.

Cinq campagnes de recensement portant sur les populations d'oursins verts (*Strongylocentrotus droebachiensis*) ont été entreprises conjointement par Pêches et Océans Canada (MPO) et une association industrielle (West Coast Green Urchin Association - WCGUA) dans le détroit de la Reine-Charlotte (Colombie-Britannique) durant les saisons d'automne 1998 à 2002. Ces campagnes s'inscrivaient dans un programme dont l'objectif stratégique était d'évaluer les fluctuations affectant les populations d'oursins verts et de surveiller les impacts de la pêche commerciale sur ces mêmes populations. Les recensements ont été effectués avant l'ouverture de la saison de pêche commerciale concernant cette espèce, dans trois pêcheries comptant des aires ouvertes et des aires fermées à la pêche commerciale. Les recensements ont été effectués par des plongeurs travaillant en plongée autonome, au moyen de la méthode transect-quadrat. Les données recueillies portaient sur la taille et l'abondance des oursins verts, le poids et la qualité des gonades, et sur la profondeur, le substrat et la végétation du milieu ambiant; les résultats sont organisés selon trois catégories de tailles.

Au cours de la période visée par l'étude, la densité et la biomasse des oursins verts de taille pêchable ont connu certaines fluctuations mais celles-ci ont généralement été à la hausse, malgré l'activité de pêche commerciale. On observe également une augmentation des densités et biomasses des oursins de taille pêchable aux endroits non concernés par l'activité de pêche, au cours des cinq ans qu'a duré l'étude. L'année de reproduction 1998 a été particulièrement féconde ainsi que l'année 1999, quoique dans une moindre mesure. On a par contre observé une baisse de densité et de biomasse chez les sujets immatures (nouvelles recrues) pour les campagnes 2000, 2001 et 2002.

INTRODUCTION

The commercial green sea urchin (*Strongylocentrotus droebachiensis*) fishery has existed in British Columbia since 1987. Hand-picking by divers is the only method allowed to harvest this species. It is currently managed using a minimum size limit of 55 mm test diameter (TD), by restricting areas and fishing seasons (usually open from November until March or April), area quotas, and by an Individual Quota (IQ) system. Fishers are required, as a condition of licence, to complete harvest logbooks and charts and submit them to Fisheries and Oceans Canada (DFO). The logbooks contain information on the dates and locations that green urchins were caught, divers' names, how long fishing was conducted each day (i.e., effort), and the total weight of urchins removed (i.e., catch). Up until 1996, these, along with sales slip data, have been the only sources of B.C. data available upon which DFO stock assessments and management decisions have been based. These data are of variable quality because of changes in fishing practices and the aggregating nature of green sea urchin distributions. The harvest logbooks also do not contain information on sublegal-sized urchins, size frequencies from the whole population, densities, roe quality and quantity, or habitat associations. Therefore, a survey protocol was developed to study interannual variability and the impacts of fishing on the green sea urchin populations. The survey design includes a site open to commercial harvesting (and consistently fished) and two nearby closed sites. Surveys were conducted in October, 1995 and March, 1996 (Waddell *et al.* 1997), November, 1996 and February, 1997 (Waddell *et al.* 2002), and in November, 1997 and March, 1998 (Waddell *et al.* 2003), to obtain this crucial information. By coordinating surveys that involved all parties with interests in the green sea urchin fishery, i.e., DFO, First Nations (first two years of surveys) and the commercial industry, there has been improved confidence and acceptance of these data. This report presents the data collected from five cooperative surveys performed by DFO and industry (West Coast Green Urchin Association or WCGUA) in November, 1998, 1999, 2000, 2001 and October, 2002. An overview and interpretation of these and other on-going surveys will be presented in a future paper.

The long-term objectives of these green sea urchin scientific surveys are to monitor population changes and to assess the impacts of the fishery on green sea urchin populations at a key fishery location. To do this, green sea urchin densities, size measurements, and samples for gonad quantity and quality were obtained, both in areas open and closed to commercial green sea urchin fishing, prior to the opening of the commercial fishery. All of the surveys have been conducted at the same location in Pacific Fisheries Management Area 12 (or PFMA 12 or Area 12, where the majority of the fishery occurs), in Queen Charlotte Strait, near Telegraph Cove (Figs. 1a-1c and 2a-2b). The Stephenson Islets met the criterion for the survey site open to commercial fishing because fishers have historically found this site to have consistently high numbers of legal-sized green sea urchins. Stubbs Island and the Plumper Islands met the criterion for monitoring population changes due to environmental variations, and are located close to the Stephenson Islets. Stubbs Island and the NW section of the Plumper Islands have been closed to commercial fishing (for research purposes) since the fall of 1995.

In the first three initial years of these surveys, (i.e., from fall 1995 to spring 1998), there was a survey just prior to the opening of the fishery (which was usually in mid-November), and then another survey shortly following the closure of the fishery (which was usually in mid-March). The length of the opening of the fishery in Area 12 varied from year to year, and was sometimes closed before the end of the season due to the fishers reaching the allowed quota for the area. Due to funding shortages and generally inclement weather in the spring, surveys carried out following the closure of the fishing season have been discontinued since March, 1998. Surveys have been conducted every fall since that time. All of the surveys discussed in this report were conducted just prior to the opening of the commercial green sea urchin fishery.

METHODS

(a) DATA COLLECTION – FIELD AND LAB

A total of five surveys were carried out, one in each of November 1998, 1999, 2000, and 2001, and in October, 2002. The green urchin surveys were designed, organized and supervised by DFO, and costs were supported by both DFO and industry. In each survey there were two dive teams (i.e., two boats), each with one industry and one DFO diver, one boat driver (industry or DFO), one dive tender (industry), and one observer/recorder (DFO). During each of the surveys, there were nine to ten transects surveyed for green sea urchins in the Stephenson Islets (50°34.5' N, 126°49.5' W), at the north end of Johnstone Strait, near Telegraph Cove and Weynton Passage (Figs. 1b and 2a), three to four transects at nearby Stubbs Island (50°36.2' N, 126°49.2' W; Fig. 1c), and four to six transects in the Plumper Islands (50°34.6' N, 126°48.0' W; Figs. 1c and 2b). The dive teams attempted to survey all of the same transects as in the six previous surveys, however, in some cases poor weather, strong currents, lack of time, or divers reaching their maximum bottom time (to avoid having to do decompression dives), prevented all of the transects from being surveyed. Table 1 shows the survey dates, the vessels involved and the number of transects surveyed at each of the sites for each survey.

The transect positions were randomly selected during the first survey in 1995 and marked on a chart prior to arriving at the survey area (Waddell *et al.* 1997, 2002). The transects ran perpendicular to the shoreline and/or depth contours (with slight adjustments of the angle to run parallel with the direction of the current), starting at 10.0 m (32.8 ft) below Chart Datum (CD) and continuing up to zero CD. A computer program called "Tides and Currents for Windows" (Nautical Software Inc. 1995) was used to calculate the tide levels for every 10 minutes so that the depth to CD could be determined before each dive commenced. A weighted line was laid from shallow to deep to mark the transect, with a surface marker buoy indicating the deep end of the line. At the start of each transect, a compass bearing was taken by the divers from the marker buoy to the shallow end. Beginning at the deep end, the divers placed a 1 m^2 aluminum quadrat on the substrate and counted and measured the test diameter (TD) (using calipers) of all sea urchins within the quadrat. All urchins were removed from the quadrat as they were being measured to avoid repeating measurements. An urchin was considered to be in a quadrat if one-half or more of its body was within the quadrat's boundaries. Sometimes green urchins were under rocks or in crevices, so all surfaces were explored in order to find all sea urchins. One diver did all of the measuring while the other diver recorded the data on waterproof paper. The depth, substrate and type of vegetation were also recorded for each quadrat, and then the quadrat frame was rolled over in the direction of the lead line (or the compass bearing when lead line could not be used), and the procedure was repeated along the full length of the transect.

The surface personnel recorded the position (using a GPS) for both the start and finish of the transects, as well as the divers' start and finish times for each transect (for use in calculating depth from CD), and the weather conditions.

Green sea urchins of various size classes (small, medium and large) were randomly collected along the transect lines during the surveys for later laboratory analyses of weight and size and to examine the quality of the roe. For all surveys, the green urchins were measured and dissected on the same day they were collected (except for November, 2000, Transects 3, 15, 16, 17, 20, 22, and for October, 2002, Transects 3, 5A, 7, 13, which were dissected the day following collection). For each urchin collected, the following data were recorded: test diameter; test height; total wet weight; drained weight; gutted weight (note that stomach and contents were removed in Nov. 1998, 1999, and Oct. 2002, but only stomach contents were removed in Nov. 2000 and 2001); gonad weight, colour and texture; and sex. Gonad colour was given a qualitative rating code of 0 (unknown (i.e., missing), or no gonad present), 1 (orange/yellow), 2 (yellow with other colours), or 3 (brown/red). Gonad texture was also given a qualitative rating code of 0 (unknown (i.e., missing), or no gonad present), 1 (firm), 2 (semi-firm), and 3 (flimsy).

(b) DATA ANALYSES

It was noted that the divers occasionally started surveying deeper than 10 m below CD, or they continued surveying shallower than 0 m CD. Since the area estimate for the Stephenson Islets is based on the area between the 0 and 10 m isobaths, and green urchins are usually sparse at depths greater than 10 m below CD, the divers' data were truncated to include only data collected between 0 and 10 m (33 ft) below CD for the overall density calculations, and for the density by substrate calculations. The original (unadjusted) data were used for all other calculations presented in this report.

Test diameter frequency distributions were analyzed using the software "MIX3aa" (Macdonald 1994) to identify dominant size modes under the assumption that individual modes were normally distributed (see Macdonald and Pitcher (1979), and Macdonald and Green (1988), for details). In general, initial parameters (mean, and standard deviation) were assigned by examination of test diameter frequency data distributions collected during the surveys at each site. The software "MIX3aa" was then used to estimate the proportions while keeping the mean and standard deviation parameters fixed. Next, estimates of mean, standard deviation, and proportion were calculated by varying the constraints on each until a reasonable fit to the data was established. This fit was determined by the goodness-of-fit chi-square statistical test and examination of the size frequency histogram with its fitted components. The software fit the means, proportions, and standard deviations of the size frequency distributions using the Quasi-Newton Algorithm technique (Macdonald and Green 1988). The test diameter frequency distributions were analyzed for data obtained at Stephenson Islets, Stubbs Island, and Plumper Islands during all surveys.

In many of the analyses, the data have been separated into three different size classes: legal-sized (TD ≥ 55 mm); sublegal-mature (25 mm ≥ TD < 55 mm); and sublegal-immature (TD < 25 mm). The mature/immature size of 25 mm TD was approximated from the dissection roe quality and maturity data, in which 100% of green urchins < 25 mm were immature (no gonad present) compared with 6% of urchins ≥ 25 mm being immature.

Mean and total densities of green urchins for each transect within each of the three survey sites (Stephenson Islets, Stubbs Island, and Plumper Island) were calculated as described by Jamieson and Schwarz (1998). These surveys are characterized by the quadrats within a transect not being independent (e.g. if one quadrat has a high number of urchins, then adjacent quadrats are likely to have high numbers as well), transect lengths vary among the transects, and all urchins within each transect are counted. These features indicate a "complete cluster" sampling design with unequal-sized clusters (Jamieson and Schwarz 1998). The appropriate calculation for the mean density (of a particular size class of urchins) is:

(1)
$$\overline{D} = \frac{\sum_{i=1}^{n} U_i}{\sum_{i=1}^{n} L_i}$$

and for the standard error of density is:

(2)
$$SE(\overline{D}) = \sqrt{\frac{1}{\overline{L}^2}\frac{1}{n}\frac{\sum (U_i - L_i\overline{D})^2}{n-1}}$$

With n = the number of transects sampled in a particular site;
U_i = the total number of urchins of the appropriate size class in transect i, $i = 1,2,\ldots,n$;
L_i = the total number of quadrats in transect i; and
$\overline{L}$ = $\frac{1}{n}\sum_{i=1}^{n} L_i$, the average area of the transects in the site.

Since the area of a quadrat was 1 m^2, L_i is also equal to the area of the transect.

In the results that follow, standard errors have not been calculated for the individual transects since the transect has been defined as the (cluster) sample unit, and therefore the (n-1) term in the denominator of the equation for the standard error goes to zero. In the calculation of urchin densities by depth range and substrate type, however, the quadrats have been considered as the sampling unit, and distributed among the various depth and substrate categories. This reduces (but does not entirely eliminate) the problem of non-independence among adjacent quadrats, and so standard errors about the mean densities for these classifications have been calculated using standard formulae (e.g. as found in Sokal and Rohlf (1981) and as implemented in the "EXCEL 2002" (Microsoft) statistical software package).

When calculating the "densities of green urchins by depth range", the actual depth below CD had to be determined for each quadrat, which depended on the ever-changing tide height. This was accomplished by first calculating the number of minutes spent at each tide height above CD (to rounded feet) over the length of each dive for each transect, by using the "Tides and Currents for Windows" program (Nautical Software Inc. 1995) set for every one minute. Then the tide height above CD was calculated for each quadrat by proportioning the dive time over the transect according to the number of quadrats in each transect. Once this was calculated, then the tide height above CD was subtracted from the depth gauge reading recorded for each quadrat, to give the approximate adjusted depth below CD. (Note that in past reports the mean tide height above CD over a transect was calculated and then this one mean value was subtracted from all of the depth gauge readings for that transect). Also note that the depth readings are initially recorded in feet and then converted to meters for the report because the depth meters only read in feet.

For substrate data, the three most abundant substrates in the quadrat were recorded, in order of prominence. The tables and figures in this report displaying the substrate data use three digit codes that represent the order of prominence and type of substrates observed. A similar recording method was used for vegetation types. However, the vegetation data were incomplete, making it difficult to interpret from the data sheets whether algae were absent or just not recorded. In addition, the divers had varying skill levels in identifying algae species, so the data were not considered reliable and are therefore not presented in this report.

The statistical software package "EXCEL 2002" (Microsoft) was used to find the best relationships (i.e. highest R^2) between TD (in millimeters) and the variables test height (in millimeters), total wet weight (in grams), and gonad weight (in grams). These were calculated from dissection data for all sites combined, and for each of the three sites separately, for each of the five surveys. The majority of the calculations had the best fit when the power equation was used (i.e., $variable = \alpha(TD)^{\beta}$), therefore this was the standard equation used for all calculations. Note that samples that had gonad weights of zero were removed from the calculations.

The mean abundance of green urchins was converted to total biomass for all of the survey sites using the mean weight of an individual urchin (separated into three size classes), the mean densities, and the total area of each site. Rather than using a single mean weight to convert abundance to biomass (as in Waddell *et al.* 1997), we used the following method (as in Waddell *et al.* 2002, 2003). The measured green urchins were separated into three size classes: legal-sized (TD ≥ 55 mm); sublegal-mature (25 mm ≥ TD < 55 mm); and sublegal-immature (TD < 25 mm). The mean weights of urchins ($\overline{W}_j$) were determined by calculating the weight of each individual urchin measured in the field survey (using the TD-weight relationships derived from the laboratory measurements), then calculating the mean weight of urchins within each size class (j). Standard errors about the mean weights ($SE(\overline{W}_j)$) within a size class were determined by calculating the standard deviation of the mean weight and dividing by the square root of the sample size. In order to resolve if the test diameter and the natural log of the total wet weight relationship could be used for all sites combined (within each survey) or if the relationship for each site had to be used separately, a test for homogeneity of the regression slopes was performed. This test was programmed in "EXCEL 2002" using equations from Zar (1984, p. 300).

The total biomass for a particular site was then calculated as

$$B = \sum_{j=1}^{3} \overline{D}_j (\overline{W}_j)(A) \tag{3}$$

where j subscripts the three size classes. The area (A) (from 0 to 10.0 m below CD) of each survey site was determined to be 485,200 m^2 for Stephenson Islets, 19,600 m^2 for Stubbs Island, and 223,600 m^2 for the Plumper Islands, based on a geographic information program called COMPUGRID (Geo-Spatial Systems Ltd. 1996).

The standard error of the total biomass for a particular site, which includes the uncertainties in the mean density and mean weight by size category, was calculated as:

$$(4) \qquad SE(B) = \left[\sum_{j=1}^{3} \left[\left(\left(\frac{SE(D)_j}{\overline{D}_j} \right)^2 + \left(\frac{SE(W)_j}{\overline{W}_j} \right)^2 \right)^{\frac{1}{2}} \left(B_j \right) \right]^2 \right]^{\frac{1}{2}},$$

with symbols as previously defined, and assuming that the area (A) (used within the calculation for B_j) is known without error. A further assumption is that the errors in mean density and mean weight, and among size classes, are independent and random.

In order to determine the impact of fishing on the stock of green sea urchins at Stephenson Islets (the roe fishery site), we calculated exploitation by the fishing industry using the following equation:

$$(5) \qquad Expl = \frac{B_{fishing}}{B_{Nov}},$$

with standard error defined by:

$$(6) \qquad SE(Expl) = (Expl)\left[\left(\frac{SE(B_{fishing})}{B_{fishing}} \right)^2 + \left(\frac{SE(B_{Nov})}{B_{Nov}} \right)^2 \right]^{\frac{1}{2}}.$$

$B_{fishing}$ is the biomass removed from the Stephenson Islets by fishing, with standard error $SE(B_{fishing})$; B_{Nov} is the pre-season biomass at the Stephenson Islets, with standard error $SE(B_{Nov})$, defined here as either the total biomass or the biomass of legal-sized urchins from the fall surveys, and *Expl* is the exploitation of green urchins (with standard error $SE(Expl)$), defined as a proportion of the pre-fishery biomass (either total or legal-sized only). The biomass removed by the fishery ($B_{fishing}$) at Stephenson Islets was determined by examining dockside validation records and charts of fishing locations submitted with these records, and tabulating the total landings. The precise error of the dockside weight measurements for validation is unknown, but considered to be small, therefore $SE(B_{fishing})$ was set at 1% of $B_{fishing}$.

Note that EXCEL spreadsheets are used for many of these calculations, and that each result from a sequence of calculations is not rounded off. Therefore, any differences between calculations and values shown in the tables are due to rounding errors.

Unlike other past reports, unmeasured urchins (i.e., "unknowns") were incorporated into the data analyses. Green urchin densities increased over the years of the surveys, until it became difficult to measure all urchins within the time and budget constraints, and it became necessary to only count urchins in every second quadrat on some transect lines. The estimates of legal and sublegal urchins within the unmeasured urchins (or "unknowns") were calculated by using the proportions of measured legal-sized and sublegal-sized urchins of all the measured urchins. To calculate the estimated total number of legal-sized urchins, the proportion of measured legal urchins of all the measured urchins on that transect was multiplied with the number of "unknowns", and then added to the number of measured legal urchins. This was similarly done with the sublegal-sized urchins. There were no unmeasured urchins in the November, 1998 survey, and very few in the 1999 survey. These adjustments of the data to include unmeasured urchins in the data analyses were done for many of the tables, including density by transect and site, density by depth range, and the biomass estimates.

RESULTS

(a) NOVEMBER 6-8, 1998 SURVEY

Ten transect lines were surveyed in the Stephenson Islets (Fig. 1b), four transects were surveyed at Stubbs Island (Fig. 1c), and five transects in the Plumper Islands (missed Transect 19; Fig. 1c). The tidal current was strong throughout most of the survey.

Size: Data were recorded for 479 quadrats over all the sites sampled during this survey, and test diameters (TD's) were measured for a total of 1,585 green urchins (Table 2). Of the TD's measured, 675 (42.6%) were of legal size, 683 (43.1%) were sublegal-mature, and 227 (14.3%) were sublegal-immature (Table 2). Figure 3a shows the size frequency distribution for all the sites combined during the November, 1998 survey. When combining all the test diameters measured at all sites during the November, 1998 survey, three distinct modes best fit the distribution ($X^2 = 172.9$; df = 38; $p < 0.0001$), with test diameter means at 8, 28 and 55 mm (Table 3). The proportions of these modes were 5%, 27% and 69%, respectively. Mean TD's and total wet weights for urchins from all sites combined were 61.2 ± 0.2 mm and 92.3 ± 1.0 g for legal-sized urchins, 42.7 ± 0.3 mm and 39.1 ± 0.6 g for sublegal-mature urchins, and 13.2 ± 0.4 mm and 2.6 ± 0.2 g for sublegal-immature urchins (Table 4).

Density: The mean overall total density during this survey (all sites combined) was 3.31 ± 0.58 urchins/m^2 (Table 5). The mean overall densities were 1.41 ± 0.38 urchins/m^2 for legal-sized urchins, 1.43 ± 0.30 urchins/m^2 for sublegal-mature urchins, and 0.47 ± 0.17 urchins/m^2 for sublegal-immature urchins.

Depth: The sample mean densities of green sea urchins by depth range for all sites combined are shown in Table 6a and Fig. 4a. The highest total mean density of green urchins for all sites combined (5.39 ± 0.74 urchins/m^2) was observed in the 0.3 to 1.5 m (1 to 5 ft) below CD range. This range included the highest density of legal-sized green sea urchins (2.71 urchins/m^2), and the highest density of sublegal green sea urchins (2.68 urchins/m^2) for all sites combined. The total mean densities generally decreased continuously with each deeper depth interval, and there were no urchins observed from 12.5 to 14.3 m (41 to 47 ft) below CD.

Substrate: Table 7a and Fig. 5a show the mean densities of green sea urchins by substrate type for all sites combined. While smooth bedrock was the most sampled substrate (181 quadrats), followed by creviced bedrock (163 quadrats), smooth bedrock with gravel and shell had the highest total density (10.00 urchins/m^2; 1 quadrat only). Looking at the data grouped by primary substrate type, the highest mean total densities occurred on creviced bedrock (4.22 ± 0.43 urchins/m^2; 181 quadrats) and on boulders (4.05 ± 0.77 urchins/m^2; 60 quadrats).

(i) Stephenson Islets

Size: Data were recorded for 1,159 green sea urchins from 287 quadrats (Table 2). Of all of the TD measurements, 501 (43.2%) were of legal size, while 523 (45.1%) were sublegal-mature and 135 (11.7%) were sublegal-immature. The size frequency distribution can be seen in Fig. 3b. The test diameter frequency analysis for the November, 1998 survey is presented in Table 3. Stephenson Islets showed the best fit ($X^2 = 157.9$; df = 34; $p < 0.0001$) with four dominant size modes with means occurring at 8, 24, 36 and 54 mm test diameter. The proportions of these four modes were 5%, 14%, 4% and 77%, respectively. Mean TD's and total wet weights for urchins from Stephenson Islets were 60.6 ± 0.3 mm and 89.9 ± 1.1 g for legal-sized urchins, 44.1 ± 0.3 mm and 41.8 ± 0.7 g for sublegal-mature urchins, and 12.8 ± 0.5 mm and 2.4 ± 0.2 g for sublegal-immature urchins (Table 4).

Density: The mean overall total density (all transects and sizes combined) at Stephenson Islets was 4.04 ± 0.86 urchins/m^2, while the mean overall legal density was 1.75 ± 0.56 urchins/m^2, the mean overall sublegal-mature density was 1.82 ± 0.49 urchins/m^2, and the mean overall sublegal-immature density was 0.47 ± 0.27 urchins/m^2 (Table 5). The mean total densities per transect ranged from 0.60 urchins/m^2 in Transect 8 to 8.35 urchins/m^2 in Transect 13 (Table 5). The highest mean densities for legal-sized urchins occurred in Transect 11 (4.63 urchins/m^2), while the highest mean density of sublegal-mature urchins occurred in Transect 5A (5.90 urchins/m^2), and the highest mean density of sublegal-immature urchins occurred in Transect 13 (2.68 urchins/m^2).

Depth: The mean total densities were highest (5.88 ± 1.00 urchins/m^2) between 0.3 to 1.5 m (1 to 5 ft) below CD, and were also high (5.22 ± 0.90 urchins/m^2) between 3.3 to 4.8 m (11 to 15 ft) below CD (Table 6b, Fig. 4b). These were the highest densities for all of the sites. The total mean densities generally became continuously lower with each deeper depth interval, down to 0.00 urchins/m^2 at 12.5 to 14.3 m (41 to 47 ft) below CD. The same general trend applied for legal and sublegal urchins, with the highest mean densities of legal urchins (3.19 urchins/m^2) occurring between 0.3 to 1.5 m (1 to 5 ft) and occurring for sublegal urchins (3.41 urchins/m^2) between 3.3 to 4.8 m (11 to 15 ft) below CD (Table 6b, Fig. 4b).

Substrate: At Stephenson Islets, the most common substrate sampled was bedrock with crevices (147 quadrats), of which the mean total density was 4.73 urchins/m^2 (Table 7b). The highest mean total density (9.00 urchins/m^2; Table 7b, Fig. 5b) occurred on creviced bedrock with shell (one quadrat only). When the data were grouped by the main or primary substrate types, creviced bedrock had the highest mean total density (4.72 ± 0.50 urchins/m^2 over 152 quadrats), whereas gravel had the lowest mean total density (0.38 ± 0.38 urchins/m^2 over 8 quadrats).

(ii) Stubbs Island

Size: Data were recorded for green sea urchins from a total of 69 quadrats, on four transects. Of the total 146 green sea urchins measured, 60 (41.1%) were of legal size, 61 (41.8%) were sublegal-mature, and 25 (17.1%) were sublegal-immature (Table 2). When analyzing the size frequency distribution (Table 3 and Fig. 3c), the best fit occurred with two modes ($X^2 = 49.1$; df = 33; p = 0.0354), with the means at 25 and 57 mm TD, and proportions of 40% and 60%, respectively. Mean TD's and total wet weights for urchins from Stubbs Island were 62.2 ± 0.9 mm and 96.7 ± 3.6 g for legal-sized urchins, 37.8 ± 1.2 mm and 29.9 ± 2.2 g for sublegal-mature urchins, and 18.5 ± 0.8 mm and 4.7 ± 0.5 g for sublegal-immature urchins (Table 4).

Density: The mean overall total (all transects and sizes combined) density at Stubbs Island was 2.12 ± 0.87 urchins/m^2 (Table 5). The mean overall total (all transects combined) densities of legal, sublegal-mature and sublegal-immature green sea urchins were 0.87 ± 0.27, 0.88 ± 0.38, and 0.36 ± 0.27, respectively. The mean total densities ranged from 0.33 urchins/m^2 in Transect 16 to 3.71 urchins/m^2 in Transect 17. The highest mean legal (1.36 urchins/m^2), sublegal-mature (1.50 urchins/m^2), and sublegal-immature (0.86 urchins/m^2) densities all occurred at Transect 17 (Table 5).

Depth: The highest mean total density (5.17 ± 2.12 urchins/m^2) occurred between 0.3 to 1.5 m (1 to 5 ft) below CD, and like the Stephenson Islets, the densities generally decreased with depth (Table 6c and Fig. 4c). The highest mean legal and sublegal densities (2.33 and 2.83 urchins/m^2, respectively) also occurred between 0.3 and 1.5 m (1 and 5 ft) below CD.

Substrate: The most frequently sampled substrate was smooth bedrock (61 quadrats; Table 7c). This main substrate had a total overall density of 2.17 ± 0.46 urchins/m^2 (Table 7c). The highest mean legal (3.00 urchins/m^2), sublegal (5.00 urchins/m^2), and total (8.00 urchins/m^2) densities occurred on a substrate of smooth bedrock with cobble and shell (1 quadrat only; Table 7c; Fig. 5c). Creviced bedrock with shell also had a legal density of 3.00 urchins/m^2 and smooth bedrock with cobble also had a sublegal density of 5.00 urchins/m^2.

(iii) Plumper Islands

Size: Data were recorded for 280 green sea urchins, from 123 quadrats on five transects in the Plumper Islands (Table 2). Of the total test measurements, 114 (40.7%) were of legal size, 99 (35.4%) were sublegal-mature, and 67 (23.9%) were sublegal-immature. The size frequency distribution for the Plumper Islands fits three modes ($X^2 = 52.3$; df = 30; p = 0.0070), with mean test diameters occurring at 6, 28 and 60 mm (Table 3, Fig. 3d). The proportions were 9%, 39% and 52% in the first, second and third mode, respectively. Mean TD's and total wet weights for urchins from the Plumper Islands were 63.1 ± 0.6 mm and 99.8 ± 2.3 g for legal-sized urchins, 38.3 ± 0.9 mm and 30.6 ± 1.7 g for sublegal-mature urchins, and 12.1 ± 0.8 mm and 2.4 ± 0.3 g for sublegal-immature urchins (Table 4).

Density: The mean overall densities of total (all sizes and transects combined), legal, sublegal-mature and sublegal-immature green sea urchins at the Plumper Islands were 2.28 ± 0.61, 0.93 ±

0.54, 0.82 ± 0.15 and 0.54 ± 0.19 urchins/m^2, respectively (Table 5). The mean total densities ranged from 1.24 urchins/m^2 in Transect 24, to 4.38 urchins/m^2 in Transect 22. The highest mean density for legal-sized (2.88 urchins/m^2) and sublegal-mature (1.19 urchins/m^2) urchins occurred in Transect 22, whereas the highest mean sublegal-immature densities (0.96 and 0.90 urchins/m^2) occurred in Transects 21 and 24, respectively.

Depth: The mean total density was highest (4.10 ± 2.01 urchins/m^2; 21 quadrats) in the 9.4 to 10.7 m (31 to 35 ft) below CD depth range, but was also high (3.64 ± 1.06 urchins/m^2) in the 0.3 to 1.5 m (1 to 5 ft) depth range where it was highest for the Stephenson Islets and Stubbs Island (Table 6d, Fig. 4d). The highest mean density of legal-sized green urchins (3.00 urchins/m^2) occurred in the 9.4 to 10.7 m (31 to 35 ft) below CD depth range, while the highest mean sublegal densities (2.36 urchins/m^2) occurred 0.3 to 1.5 m (1 to 5 ft) below CD (Table 6d).

Substrate: The highest mean total (10.00 urchins/m^2) and sublegal (10.00 urchins/m^2) densities of green urchins occurred on smooth bedrock with gravel and shell (1 quadrat only; Table 7d and Fig. 5d). The highest legal density (3.89 urchins/m^2) occurred on boulders (18 quadrats). The primary substrate with the highest total density of green urchins (4.86 ± 1.49 urchins/m^2) was boulders (Table 7d).

(iv) Dissection Data

There were a total of 128 green sea urchins of various sizes, from random locations and depths that were measured, weighed and sampled for roe quantity and quality in the lab during this survey (Table 8). All mean measurements (i.e., mean test height, mean total wet weight, mean drained weight, mean gutted weight, mean stomach and content weight, and mean gonad weight) taken of the randomly selected legal-sized urchins (n=64) were larger for Stubbs Island (except for mean test diameter, which was smallest). However, measurements from Stubbs Island also had larger standard errors due to the low sample size. These same measurements were very similar between legal-sized urchins from Stephenson Islets and the Plumper Islands (Table 8). The mean test diameters were largest in the Plumper Islands (62.8 mm), followed by the Stephenson Islets (62.1 mm), and Stubbs Island (62.0 mm). These results are different when compared with the field survey data, where the mean legal test diameters and total wet weights were largest at the Plumper Islands, second largest at Stubbs Island, and smallest at the Stephenson Islets (Table 4).

A test for homogeneity showed no significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log transformation (to approximate normality) of the total wet weight for each of the three sites separately (F value = 2.10 with df = 2, 125 and $p > 0.05$). This allowed the allometric equation ($W=\alpha TD^{\beta}$) to be used for all sites in the November, 1998 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters) (Figs. 6 and 7), TD (in millimeters) and total wet weight (in grams) (Figs. 8 and 9), and TD (in millimeters) and gonad weight (in grams) (Figs. 10 and 11), for all sites combined and for each of the three sites separately, using EXCEL (see figures for equations).

Amongst the legal-sized green urchins, those from Stubbs Island had the best quality roe (i.e., orange/yellow colour and firm texture), with 66.7% having the highest quality, followed by the Plumper Islands with 57.9% and Stephenson Islets with 55.6% (Table 9). Amongst the sublegal urchins, those from Stubbs Island (87.5%) also had the best quality roe, followed by Stephenson Islets (71.1%) and then Stubbs Island (63.6%). Legal-sized urchins from Stubbs Island also had the highest (20.2%) overall roe recovery rate (total gonad weight (all grades) divided by the total drained weight of all urchins collected) followed by legal-sized urchins from the Stephenson Islets (18.7%) and the Plumper Islands (18.6%; Table 9).

(v) Biomass Estimates

Stephenson Islets is estimated to have an area of 485,200 m^2 between 0.0 and 10.0 m (0.0 and 32.8 ft) below CD. By extrapolating the total mean density in November, 1998 (4.04 ± 0.86 urchins/m^2; Table 5), there were 1,959,397 ± 416,308 green sea urchins of all sizes in November, 1998, at Stephenson Islets (Table 10). (Note that EXCEL spreadsheets are used to make these calculations and that each sequential calculation is not rounded off. Therefore, any differences between calculations and values shown in the tables are due to rounding errors). Of these, 846,987 ± 270,812 were of legal size, and 1,112410 were of sublegal size (884,180 ± 238,771 mature-sized and 228,230 ± 132,111 immature). As described in the Methods section, the weight of each individual urchin measured in the field survey was calculated using the TD-weight relationships derived from the laboratory measurements, and then the mean individual weight was calculated for each of the three size classes. Using the TD-weight relationship for all sites combined (Fig. 8), the mean weight per legal-sized green sea urchin from Stephenson Islets was determined to be 89.9 g, the mean weight per sublegal-mature-sized green urchin was determined to be 41.8 g, and the mean weight per sublegal-immature-sized green urchin was 2.4 g (Table 4). These values were then multiplied with the "total numbers" calculated above to obtain the total biomass for each size class. The total biomasses of legal-sized, sublegal-mature and sublegal-immature green sea urchins at Stephenson Islets in November, 1998 were 76.14, 36.96 and 0.55 t, respectively, for an overall total biomass of 113.64 ± 26.33 t (Table 10).

Stubbs Island is estimated to have an area of 19,600 m^2 between 0.0 and 10.0 m (0.0 and 32.8 ft) below CD. By extrapolation from the mean densities (Table 5), there were 41,472 ± 17,139 green sea urchins of all sizes (17,043 ± 5,287 legal-sized, 17,328 ± 7,479 sublegal-mature-sized and 7,101 ± 5,276 sublegal-immature-sized) at Stubbs Island in November, 1998 (Table 10). The mean weights for individual legal-sized, sublegal-mature, and sublegal-immature urchins at Stubbs Island were 96.7, 29.9, and 4.7 g, respectively (Table 4). The total biomasses of legal-sized, sublegal-mature, and sublegal-immature green sea urchins at Stubbs Island in November, 1998 were 1.65, 0.52 and 0.03 t, respectively, for an overall total biomass of 2.20 ± 0.56 t (Table 10).

The survey site in the Plumper Islands has an area of approximately 223,600 m^2 between 0.0 and 10.0 m (0.0 and 32.8 ft) below CD. By extrapolating the mean densities (Table 5), there was a total abundance of 509,008 ± 135,268 green sea urchins (207,239 ± 119,713 legal-sized, 179,971 ± 33,444 sublegal-mature-sized and 121,798 ± 43,366 sublegal-immature) at the Plumper Islands in November, 1998 (Table 10). The mean weights of legal, sublegal-mature and sublegal-immature green urchins in the Plumper Islands in November, 1998 were 99.8, 30.6, and 2.4 g

(Table 4). The biomasses of legal-sized, sublegal-mature, and sublegal-immature green sea urchins at the Plumper Islands in November, 1998 were 20.68, 5.52 and 0.29 t, respectively, for an overall total biomass of 26.48 ± 12.00 t (Table 10).

(b) NOVEMBER 2-4, 1999 SURVEY

In this survey there was one less transect surveyed at the Stephenson Islets (9 transects instead of 10, missed Transect 11; Fig. 1b) due to strong tidal currents, four at Stubbs Island (Fig. 1c), and six in the Plumper Islands. The tidal current was strong and winds were steady throughout most of the survey.

Size: There were 2,731 test diameter measurements recorded for green sea urchins from a total of 561 quadrats during the whole survey (Table 2). It was observed that 936 (34.3%) of the green urchins were of legal size, 1,497 (54.8%) were sublegal-mature, and 296 (10.8%) were sublegal-immature (Table 2, corrected for unknowns). The size frequency distribution for all sites combined is presented in Fig. 12a. When analyzing the combined data for all of the test diameter measurements taken during the entire survey, two dominant size modes fit the data best ($X^2 = 229.0$; df = 37; $p < 0.0001$) with test diameter means of 33 and 59 mm (Table 3). The proportions for these modes were 58% and 42%, respectively. Mean TD's and total wet weights for urchins from all sites combined were 62.7 ± 0.2 mm and 84.6 ± 0.8 g for legal-sized urchins, 38.4 ± 0.2 mm and 24.6 ± 0.3 g for sublegal-mature urchins, and 18.1 ± 0.3 mm and 3.4 ± 0.1 g for sublegal-immature urchins (Table 11).

Density: The mean overall total density (all sites and size categories combined) for this survey was 4.87 ± 0.79 urchins/m^2 (Table 12). The mean overall legal, sublegal-mature, and sublegal-immature densities for November, 1999 were 1.67 ± 0.40, 2.67 ± 0.45, and 0.53 ± 0.09 urchins/m^2, respectively.

Depth: The sample mean densities of green sea urchins by depth range for all sites combined are shown in Table 13a and Fig. 13a. The highest overall mean total densities (7.12 ± 1.07 to 7.91 ± 0.88 urchins/m^2) of green sea urchins (for all sites combined) were found between 1.2 m (4 ft) above CD to 3.0 m (10 ft) below CD, and densities gradually decreased above and below this depth range. The highest legal density (2.98 urchins/m^2) occurred between 1.8 and 3.0 m (6 to 10 ft) below CD, whereas the highest density of sublegal green sea urchins (5.57 urchins/m^2) occurred between 1.2 m (4 ft) above CD to zero CD (Table 13a).

Substrate: Table 14a and Fig. 14a show the mean densities of green sea urchins by substrate type for all sites combined. Creviced bedrock was the most frequently surveyed substrate (284 quadrats). High total densities occurred on substrates of cobble with boulders and shell (34.0 urchins/m^2), boulders with cobble and creviced bedrock (32.0 urchins/m^2), and boulders with creviced bedrock (31.00 urchins/m^2; all with only 1 quadrat each; Table 14a), and they were all comprised of high densities of both legal (18.00 to 22.00 urchins/m^2) and sublegal (10.00 to 16.00 urchins/m^2) urchins. Pea gravel was the primary substrate with the highest overall total density (13.50 ± 4.50 urchins/m^2; 2 quadrats only).

(i) Stephenson Islets

Size: There were 311 quadrats surveyed and 1,865 test measurements recorded for green sea urchins in the Stephenson Islets, of which 33.8% were of legal size, 56.0% were sublegal-mature, and 10.1% were sublegal-immature (Table 2, corrected for unknowns). Fig. 12b shows the size frequency distribution. Stephenson Islets showed two dominant size modes ($X^2 = 166.8$; df = 35; $p < 0.0001$) where mean test diameters occurred at 35 mm (62%) and 59 mm (38%; Table 3). Mean TD's and total wet weights for urchins from the Stephenson Islets were 61.6 ± 0.2 mm and 80.5 ± 0.8 g for legal-sized urchins, 39.0 ± 0.2 mm and 25.5 ± 0.4 g for sublegal-mature urchins, and 17.8 ± 0.4 mm and 3.3 ± 0.1 g for sublegal-immature urchins (Table 11).

Density: The mean overall total density (all sizes combined) at the Stephenson Islets was 6.00 ± 0.72 urchins/m^2 (Table 12). The mean overall legal, sublegal-mature and sublegal-immature densities were 2.03 ± 0.50, 3.36 ± 0.54, and 0.60 ± 0.08 urchins/m^2, respectively. The highest mean legal density (5.90 urchins/m^2) occurred on Transect 3, while the highest sublegal-mature density (6.21 urchins/m^2) occurred on Transect 13 and the highest sublegal-immature densities (0.88 urchins/m^2) occurred on both Transects 10 and 14. The lowest densities for legal (0.36 urchins/m^2), sublegal-mature (1.07 urchins/m^2) and sublegal-immature (0.14 urchins/m^2) all occurred on Transect 5A.

Depth: The highest mean total (7.94 to 9.28 urchins/m^2) and sublegal (5.83 to 6.19 urchins/m^2) densities occurred between 1.2 m (4 ft) above CD and 3.0 m (10 ft) below CD. The highest mean legal densities (2.56 to 3.17 urchins/m^2) occurred below that, between 1.8 and 6.1 m (6 and 20 ft) below CD (Table 13b and Fig. 13b). The general trend was that the densities continuously decreased both above and below these depth ranges.

Substrate: The green urchin densities for the Stephenson Islets by substrate type are presented in Table 14b and Fig. 14b. The highest mean total density (18.00 urchins/m^2) for the Stephenson Islets occurred on smooth bedrock with cobble. The highest mean legal density (10.00 urchins/m^2) occurred on cobble with creviced bedrock, while the highest mean sublegal density (16.00 urchins/m^2) occurred on smooth bedrock with cobble. Pea gravel was the main substrate with the highest total density (13.50 ± 4.50 urchins/m^2; Table 14b).

(ii) Stubbs Island

Size: There were 88 quadrats surveyed at Stubbs Island and 659 green sea urchin TD's measured (Table 2). Legal, sublegal-mature and sublegal-immature-sized green urchins represented 44.2%, 46.7%, and 9.1%, respectively, of the sample (Table 2, corrected for unknowns). Figure 12c shows the size frequency distribution. The test diameter frequency distribution for Stubbs Island showed the best fit with two dominant size modes ($X^2 = 73.1$; df = 36; $p = 0.0003$; Table 3). The mean test diameters for the modes were 33 mm and 62 mm, both with proportions of 50%. Mean TD's and total wet weights for urchins from Stubbs Island were 64.8 ± 0.4 mm and 93.3 ± 1.6 g for legal-sized urchins, 38.8 ± 0.4 mm and 25.1 ± 0.7 g for sublegal-mature urchins, and 18.4 ± 0.6 mm and 3.5 ± 0.2 g for sublegal-immature urchins (Table 11).

Density: The mean overall total density for Stubbs Island was 7.49 ± 1.78 urchins/m^2 (Table 12). The mean overall legal, sublegal-mature, and sublegal-immature densities were 3.31 ± 0.86, 3.50 ± 0.86, and 0.68 ± 0.25 urchins/m^2, respectively. The highest mean total (10.81 urchins/m^2), legal (6.19 urchins/m^2), and sublegal-immature (0.63 urchins/m^2) densities of green sea urchins all occurred on Transect 15, while the highest sublegal-mature (4.87 urchins/m^2) density occurred on Transect 17 (Table 12). All size categories had lowest densities in Transect 18.

Depth: The highest mean total (12.64 urchins/m^2) and legal (6.86 urchins/m^2) densities of green sea urchins occurred between 0.3 to 1.5 m (1 to 5 ft) below CD, while the highest mean sublegal (7.05 urchins/m^2) densities occurred between 1.2 m (4 ft) above CD and zero CD (Table 13c, Fig. 13c).

Substrate: The green urchin densities for Stubbs Island by substrate type are presented in Table 14c and Fig. 14c. The results of the highest mean total densities for Stubbs Island are the same as described above for the whole survey area because they all occurred at Stubbs Island (34.00 urchins/m^2 in cobble with boulders and shell; 32.00 urchins/m^2 in boulders with cobble and creviced bedrock, and 31.00 urchins/m^2 in boulders with creviced bedrock). As mentioned above for the whole survey, these substrates were comprised of high densities of both legal-sized (18.00 to 22.00 urchins/m^2) and sublegal-sized (10.00 to 16.00 urchins/m^2) urchins. The main substrate with the highest density was cobble (34.00 ± 0.00; 1 quadrat only; Table 14c).

(iii) Plumper Islands

Size: There were 162 quadrats surveyed and 207 green urchin TD measurements recorded in the Plumper Islands (Table 2). Of these urchins, only 14 (6.8%) were of legal size, 145 (70.1%) were sublegal-mature, and 48 (23.2%) were sublegal-immature (Table 2). Figure 12d presents the size frequency distribution. Analyses of the test diameter frequency data showed the best fit (X^2 = 78.0; df = 25; p <0.0001) resulted with four dominant size modes, at 27 mm (82%), 45 mm (11%), 60 mm (5%) and 73 mm (2%; Table 3). Mean TD's and total wet weights for urchins from the Plumper Islands were 64.4 ± 1.7 mm and 91.5 ± 6.9 g for legal-sized urchins, 32.8 ± 0.6 mm and 16.1 ± 0.8 g for sublegal-mature urchins, and 18.8 ± 0.6 mm and 3.6 ± 0.3 g for sublegal-immature urchins (Table 11).

Density: The mean overall total density for the Plumper Islands was 1.28 ± 0.43 urchins/m^2 (Table 12). The mean overall legal, sublegal-mature, and sublegal-immature densities were 0.09 ± 0.02, 0.90 ± 0.41, and 0.30 ± 0.19 urchins/m^2, respectively. The highest mean total, legal, sublegal-mature, and sublegal-immature densities (3.24, 0.17, 1.93 and 1.14 urchins/m^2, respectively) all occurred on Transect 22. No green urchins occurred on Transect 19 (15 quadrats).

Depth: The highest mean total (2.75 urchins/m^2) and sublegal (2.71 urchins/m^2) densities occurred between 3.3 and 4.8 m (11 and 15 ft) below CD (Table 13d; Fig. 13d; 24 quadrats). The highest mean legal density (0.30 urchins/m^2) occurred between 11.0 to 12.2 m (36 to 40 ft) below CD.

Substrate: The highest mean total density (7.33 urchins/m^2) occurred on creviced bedrock with boulders and was comprised entirely of sublegal urchins (Table 14d; 3 quadrats; Fig. 14d). The highest mean legal density of green urchins (0.25 urchins/m^2) was observed on a substrate of cobble, gravel and shell (4 quadrats; Table 14d). Many substrate types had no legal-sized urchins present.

(iv) Dissection Data

There was a total of 158 green urchins collected from the transects and dissected during this survey (Table 15). Legal-sized green urchins randomly collected and observed in the lab were largest for Stubbs Island for all of the measurements presented in Table 15, followed by urchins from the Plumper Islands and then the Stephenson Islets (except the mean gonad weight was larger for those from Stephenson Islets than for the Plumper Islands). This same conclusion was reached for the field measurements presented in Table 11.

A test for homogeneity showed that there was no significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log of the total wet weight for the three sites separately ($F = 2.53$ with $df = 2, 155$ and $p > 0.05$). This allowed the allometric equation $(W = \alpha TD^{\beta})$ to be used for all sites in the November, 1999 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters) (Figs. 15 and 16), TD (in millimeters) and total wet weight (in grams) (Figs. 17 and 18), and TD (in millimeters) and gonad weight (in grams) (Figs. 19 and 20), for all sites combined, and for each of the three sites separately, using EXCEL (see figures for equations).

The highest percentage of the best quality roe (i.e., orange/yellow colour and firm texture) for legal-sized urchins was observed at the Plumper Islands (72.7%), while the lowest percentage (53.3%) occurred at the Stephenson Islets (Table 9). However, the Plumper Islands had the lowest (17.2%) mean legal roe recovery rate (total gonad weight (all grades) divided by the total drained weight of all urchins collected) while Stubbs Island had the highest legal-sized roe recovery rate (22.2%; Table 9).

(v) Biomass Estimates

By extrapolating the total mean density (6.00 urchins/m^2; Table 12) over the area of Stephenson Islets, there were 2,909,640 ± 349,493 green sea urchins of all sizes on November 4, 1999 (Table 16). Of these, 984,441 ± 240,675 were of legal size, 1,628,774 ± 261,025 were of sublegal-mature size, and 293,304 ± 40,716 were of an immature size. The test for homogeneity (described in the previous section) indicated that there was no significant difference between the slopes of the length-weight regressions from the lab dissection data for the three sites. Therefore the TD-total wet weight relationship for all sites combined (Fig. 17) was applied to all test diameter measurements recorded in the field, and then mean individual weights were calculated for each of the three size classes for each site. The mean individual weights at the Stephenson Islets in November, 1999 were determined to be 80.5 ± 0.8 g for legal-sized urchins, 25.5 ± 0.4 g for sublegal-mature-sized, and 3.3 ± 0.1 g for sublegal-immature-sized green urchins (Table 11). The individual weights were multiplied with the abundances presented above to derive the total biomass for each site and size class. The biomasses of legal-sized, sublegal-mature-sized, and sublegal-immature-sized green sea urchins at Stephenson Islets in November, 1999 were 79.22 ± 19.37, 41.57 ± 6.67, and 0.95 ± 0.13 t, respectively, for a total biomass (not including "unknowns") of 121.74 ± 20.49 t (Table 16).

On November 4, 1999, there were 146,777 ± 34,888 green sea urchins in total (64,814 ± 16,834 legal-sized, 68,600 ± 16,813 sublegal-mature, and 13,364 ± 4,966 of an immature size) at Stubbs Island (Table 16). Based on the TD-total wet weight relationship calculated for all sites combined (Fig. 17), the mean weight per legal-sized green urchin was 93.3 ± 1.6 g (Table 11). The mean weights per sublegal-mature and sublegal-immature green urchin were 25.1 ± 0.7 g and 3.5 ± 0.2 g, respectively. The total biomass was calculated as 7.82 t ± 1.63 t, of which 6.05 ± 1.57, 1.73 ± 0.42, and 0.05 ± 0.02 t were comprised of legal, sublegal-mature and sublegal-immature urchins, respectively (Table 16).

At the Plumper Islands survey site on November 4, 1999, there were 285,711 ± 95,932 green sea urchins (19,323 ± 4,877 legal-sized, 200,136 ± 92,058 sublegal-mature, and 66,252 ± 43,365 sublegal-immature; Table 16). Based on the TD versus total wet weight relationship calculated for all of the sites combined (Fig. 17), the mean weights per legal-sized, sublegal-mature-sized and sublegal-immature green urchin were 91.5 ± 6.9, 16.1 ± 0.8, and 3.6 ± 0.3 g (Table 11). The total biomass was 5.22 ± 1.56 t, which was comprised of 1.77 ± 0.46 t of legal-sized urchins, 3.21 ± 1.49 t of sublegal-mature urchins, and 0.24 ± 0.16 t of sublegal-immature green urchins (Table 16).

(c) NOVEMBER 2, 4-5, 2000 SURVEY

There were 8½ transects surveyed in the Stephenson Islets (missed all of Transect 10 and the upper half of Transect 3; Fig. 1b), three surveyed at Stubbs Island (missed Transect 18; Fig. 1c), and four surveyed at the Plumper Islands. It was decided this year to permanently drop Transects 19 and 24 from the Plumper Group since there are rarely green urchins observed on these transects, and they are difficult to survey. The current was very strong on the last day of the survey, so on Transect 3 the divers counted the green urchins in every quadrat, but only measured them in every second quadrat.

Size: During this survey, 519 quadrats were measured and 10 more were counted only, for a total of 529 quadrats. There 2,769 green urchins counted during this survey, of which 2,740 were measured (Table 2). The unknowns (unmeasured urchins) were proportioned into legal and sublegal values using the ratios from the measured data, and added to the original legal and sublegal values. The unknowns were then assigned a value of zero. After these calculations, there were 803 or 29.0% of legal size, 1,783 (64.4%) sublegal-mature, and 183 (6.6%) sublegal-immature (Table 2). The size frequency distribution for all the sites combined during the November, 2000 survey is presented in Fig. 21a. Two distinct modes best fit the size distribution when combining all the test diameters measured at all sites during the November, 2000 survey (X^2 = 191.2; df = 37; p <0.0001; Table 3). The mode means occurred at 31 and 51 mm TD, with proportions of 25% and 75%, respectively (Table 3). Mean TD's and total wet weights for urchins from all sites combined were 61.1 ± 0.2 mm and 78.8 ± 0.7 g for legal-sized urchins, 42.5 ± 0.2 mm and 31.2 ± 0.3 g for sublegal-mature urchins, and 17.2 ± 0.4 mm and 3.0 ± 0.1 g for sublegal-immature urchins (Table 17).

Density: The mean overall total density during this survey (all sites combined) was 5.23 ± 0.64 urchins/m^2 (Table 18). After adjusting for unmeasured urchins, the mean overall legal density was 1.52 ± 0.20 urchins/m^2, the mean overall sublegal-mature density was 3.37 ± 0.51 urchins/m^2, and the mean overall sublegal-immature density was 0.35 ± 0.07 urchins/m^2.

Depth: In general, the densities were highest in the shallowest depth range (0.9 m or 3 ft above CD to zero CD) for all size categories, and then gradually decreased with depth (Table 19a; Fig. 22a). The total (all sizes combined) mean densities ranged from 0.86 urchins/m^2 in the deepest depth range (11.0 to 11.3 m or 36 to 37 ft) to 11.29 urchins/m^2, in the shallowest range. The highest legal densities (3.01, 3.00 and 2.98 urchins/m^2) occurred between 3.3 and 4.8 m (11 to 15 ft) below CD, between 0.9 m or 3.0 ft above CD to zero CD, and between 0.3 to 1.5 m (1 to 5 ft), respectively. The highest sublegal density (8.29 urchins/m^2) occurred between 0.9 m (3 ft) above CD to zero CD.

Substrate: Table 20a and Fig. 23a show the mean densities of green sea urchins by substrate type for all sites combined. Smooth bedrock was the most sampled substrate (195 quadrats), and smooth bedrock with gravel had the highest total density (31.00 urchins/m^2; 2 quadrats). The primary substrate types with the highest mean total densities were creviced bedrock (7.73 ± 0.74 urchins/m^2; 78 quadrats) and boulders (7.21 ± 1.01 urchins/m^2; 85 quadrats), whereas shell had the lowest mean total density (0.55 ± 0.21 urchins/m^2; 11 quadrats).

(i) Stephenson Islets

Size: At the Stephenson Islets, 331 quadrats were measured and 10 more were counted only (341 quadrats in total). There were 1,639 green sea urchins counted at this site, of which 1,610 were measured (Table 2). Again, the unknowns (unmeasured urchins) were proportioned into legal and sublegal values using the ratios from the measured data, and then added to the original legal and sublegal values, and the unknowns were then assigned a value of zero. There were 395 (24.1%) legal-sized, 1,133 (69.1%) sublegal-mature and 111 (6.8%) sublegal-immature green urchins measured at this site (Table 2). The size frequency distribution for the November, 2000 survey is presented in Fig. 21b and Table 3 presents the test diameter frequency analysis. Stephenson Islets had the best fit ($X^2 = 138.2$; df = 32; $p < 0.0001$) with two dominant size modes. The means occurred at 10 and 46 mm test diameter, with proportions of 3% and 97%, respectively. Mean TD's and total wet weights for urchins from Stephenson Islets were 60.3 ± 0.2 mm and 75.9 ± 0.9 g for legal-sized urchins, 42.5 ± 0.2 mm and 30.9 ± 0.4 g for sublegal-mature urchins, and 15.6 ± 0.5 mm and 2.5 ± 0.2 g for sublegal-immature urchins (Table 17).

Density: After adjusting for the unmeasured urchins, the mean total (all sizes combined), legal, sublegal-mature and sublegal-immature densities at Stephenson Islets were 4.81 ± 0.87, 1.16 ± 0.14, 3.32 ± 0.78, and 0.33 ± 0.10 urchins/m^2, respectively, (Table 18). The highest mean total density (10.82 urchins/m^2) occurred on Transect 13, where the highest mean sublegal-mature

(8.62 urchins/m^2) and sublegal-immature (1.06 urchins/m^2) densities also occurred. The highest legal density (1.68 urchins/m^2) occurred on Transect 7. Transect 6 had the lowest mean total density (1.88 urchins/m^2) and lowest sublegal-mature density (1.02 urchins/m^2), while Transect 3 had the lowest legal density (0.44 urchins/m^2), and Transect 11 had the lowest sublegal-immature density (0.08 urchins/m^2; Table 18). Due to very high currents, only the deeper portion of Transect 3 was surveyed, where the densities are generally lower, so the density for this transect may be underestimated.

Depth: The highest mean total (15.17 ± 3.66 urchins/m^2), legal (4.58 urchins/m^2), and sublegal (10.58 urchins/m^2) densities all occurred in the shallowest depth range, from 0.6 m (2 ft) above CD to zero CD (Table 19b; Fig. 22b). As observed in past surveys, the mean densities generally became continuously lower with each deeper depth interval, down to the lowest densities (1.20, 0.00 and 1.20 urchins/m^2 for total, legal and sublegal densities, respectively) at 11.0 to 11.3 m (36 to 37 ft) below CD.

Substrate: The most frequently sampled substrate at Stephenson Islets was smooth bedrock (114 quadrats; Table 20b, Fig. 23b). The highest legal density (3.11 urchins/m^2) occurred on a substrate of boulders, whereas the highest sublegal density (14.00 urchins/m^2) occurred on a substrate of creviced bedrock with shell. The highest mean total density (16.00 urchins/m^2) also occurred on a substrate of creviced bedrock with shell (one quadrat). When the data were grouped by the main or primary substrate type, both creviced bedrock and boulders had the highest mean total density (7.31 ± 0.80 urchins/m^2 over 68 quadrats, and 7.31 ± 1.60 urchins/m^2 over 48 quadrats, respectively), whereas gravel had the lowest total density (1.46 ± 0.45 urchins/m^2 over 13 quadrats).

(ii) Stubbs Island

Size: Three transects were surveyed at Stubbs Island, for a total of 64 quadrats. There was a total of 519 green sea urchins measured, of which 197 (38.0%) were of legal size, 281 (54.1%) were sublegal-mature, and 41 (7.9%) were sublegal-immature (Table 2). When analyzing the size frequency distribution (Table 3 and Fig. 21c), the best fit occurred with two modes ($X^2 = 70.6$; df = 36; $p < 0.0005$), with the means at 21 and 52 mm TD, and proportions of 10% and 90%, respectively. Mean TD's and total wet weights for urchins from Stubbs Island were 62.6 ± 0.5 mm and 84.8 ± 1.9 g for legal-sized urchins, 45.5 ± 0.4 mm and 36.8 ± 0.8 g for sublegal-mature urchins, and 19.0 ± 0.6 mm and 3.6 ± 0.3 g for sublegal-immature urchins (Table 17).

Density: The mean overall (all transects combined) densities at Stubbs Island were 8.11 ± 0.73 urchins/m^2 for the total (all sizes combined), 3.08 ± 0.31 urchins/m^2 for legal-sized, 4.39 ± 0.71 urchins/m^2 for sublegal-mature, and 0.64 ± 0.14 urchins/m^2 for sublegal-immature green urchins (Table 18). The mean total densities ranged from 6.89 urchins/m^2 in Transect 16 to 9.14 urchins/m^2 in Transect 17 (Table 18).

Depth: The highest mean total densities occurred between 0.3 to 1.5 m (1 to 5 ft) below CD (11.92 ± 1.38 urchins/m^2), and between 3.3 to 4.8 m (11 to 15 ft) below CD (10.85 ± 1.16 urchins/m^2; Table 19c and Fig. 22c). These depth ranges are also where the highest mean legal densities (4.58 and 4.08 urchins/m^2, respectively) and highest mean sublegal densities (7.33 and 6.77 urchins/m^2, respectively) occurred.

Substrate: The most frequently sampled substrate was smooth bedrock (31 quadrats; Table 20c). The mean total density ranged from 2.00 urchins/m^2 on cobble to 9.75 urchins/m^2 on creviced bedrock (Table 20c, Fig. 23c). The highest mean legal density (5.75 urchins/m^2; 8 quadrats) also occurred on creviced bedrock, while the highest mean sublegal density (6.10 urchins/m^2; 31 quadrats) occurred on smooth bedrock.

(iii) Plumper Islands

Size: There were 611 green sea urchins measured in the Plumper Islands, from 124 quadrats on four transects. Of the total TD measurements, 211 (34.5%) were of legal size, 369 (60.4%) were sublegal-mature, and 31 (5.1%) were sublegal-immature (Table 2). The size frequency distribution for the Plumper Islands best fits two modes ($X^2 = 73.6$; df = 32; $p < 0.0001$; Table 3; Fig. 21d). The mean test diameters occurred at 32 and 55 mm, with proportions of 39% and 61%, respectively. Mean TD's and total wet weights for urchins from the Plumper Islands were 61.1 ± 0.4 mm and 78.8 ± 1.5 g for legal-sized urchins, 40.3 ± 0.5 mm and 27.7 ± 0.8 g for sublegal-mature urchins, and 20.2 ± 0.7 mm and 4.1 ± 0.3 g for sublegal-immature urchins (Table 17).

Density: The mean overall densities for the Plumper Islands were 4.93 ± 0.93 urchins/m^2 for the total (all sizes and transects combined), 1.70 ± 0.51 urchins/m^2 for legal-sized, 2.98 ± 0.45 urchins/m^2 for sublegal-mature-sized, and 0.25 ± 0.04 urchins/m^2 for sublegal-immature-sized green sea urchins (Table 18). The highest mean total (7.42 urchins/m^2), legal (3.19 urchins/m^2) and sublegal-mature (4.00 urchins/m^2) densities all occurred at Transect 21, while the highest sublegal-immature density (0.33 urchins/m^2) occurred at Transect 22. The lowest mean total density (0.31 urchins/m^2) as well as the lowest densities for all other size categories all occurred at Transect 23.

Depth: At this site, the highest mean total (9.29 ± 1.18 urchins/m^2), legal (2.95 urchins/m^2) and sublegal (6.33 urchins/m^2) densities all occurred in the 3.3 to 4.8 m (11 to 15 ft) below CD depth range (Table 19d; Fig. 22d). The second highest densities for all of these same size categories (7.00 ± 2.52, 2.40, and 4.60 urchins/m^2, respectively) occurred in the 0.3 to 1.5 m (1 to 5 ft) depth range. The densities became increasingly lower with each depth interval below the depth range with the highest density.

Substrate: The highest mean total (31.00 urchins/m^2), legal (9.50 urchins/m^2) and sublegal (21.50 urchins/m^2) densities occurred on smooth bedrock with gravel (2 quadrats only; Table 20d and Fig. 23d). The primary substrate with the highest total density of green urchins (14.00 ± 10.00 urchins/m^2) was creviced bedrock; however there was a high standard error due to the small sample size (2 quadrats; Table 20d). No green urchins were present on smooth bedrock with pea gravel (1 quadrat), or on gravel with cobble (3 quadrats).

(iv) Dissection Data

There were 123 green sea urchins that were randomly collected from all locations, measured, weighed and sampled for roe quantity and quality in the lab during this survey (Table 21). There were no sublegal-immature green urchins collected during this survey. The legal-sized green urchins randomly selected from Stubbs Island had the largest mean test diameter, mean total wet weight, mean drained weight, mean gutted weight, and mean gonad weight, whereas legal-sized green urchins randomly collected from the Stephenson Islets had the largest mean test height and mean stomach content weight. Legal-sized urchins from the Plumper Islands generally had the smallest values of these measurements, however, legal urchins from the Stephenson Islets had the smallest mean gutted weight and the smallest mean gonad weight. Measurements of urchins from Stubbs Island and the Plumper Islands generally had larger standard errors due to smaller sample sizes. These results are slightly different when compared with the field survey data, where the mean legal test diameters and total wet weights were largest at Stubbs Island, second largest at the Plumper Islands, and smallest at the Stephenson Islets (Table 17).

There was no significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log of the total wet weight for the three sites separately ($F = 0.40$ with $df = 2, 120$ and $p > 0.05$) when a test for homogeneity was performed. Therefore the allometric equation $(W=\alpha TD^{\beta})$ could be used for all sites in the November, 2000 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters; Figs. 24 and 25), TD (in millimeters) and total wet weight (in grams; Figs. 26 and 27), and TD (in millimeters) and gonad weight (in grams; Figs. 28 and 29), for all sites combined, and for each of the three sites separately, using EXCEL (see figures for equations).

Legal-sized green urchins collected from Stubbs Island had the highest percentage (91.7%) of the best quality roe (i.e., orange/yellow colour and firm texture), and the highest (23.0%) mean roe recovery rate (total gonad weight (all grades) divided by the total drained weight of all urchins collected; Table 9). Legal-sized urchins from the Stephenson Islets had the lowest percentage (58.1%) of the best quality roe and the lowest mean roe recovery rate (17.7%; Table 9).

(v) Biomass Estimates

It was estimated that there was a total of 2,332,090 ± 422,646 green sea urchins of all sizes on November 5, 2000 at the Stephenson Islets (Table 22). This was calculated by extrapolating the total mean density (4.81 urchins/m^2; Table 18) over the area of Stephenson Islets that was between zero and 10 m below CD. There were 562,035 ± 65,606 legal-sized, 1,612,116 ± 379,217 sublegal-mature-sized, and 157,939 ± 48,174 sublegal-immature-sized green urchins. As described in the previous section, the test for homogeneity of the lab dissection data showed there was no significant difference between the slopes of the TD-total wet weight relationship for the three sites. Therefore, the TD-weight relationship for all sites combined (Fig. 26) was applied to all test diameter measurements recorded in the field to estimate the weights of each measured urchin. Then mean weights were calculated for each of the three size classes for each of the sites. Individual legal-sized green sea urchins at Stephenson Islets had a mean total weight of 75.9 ± 0.9 g in November, 2000 (Table 17). Using the same TD-weight relationship, the mean weights per sublegal-mature-sized and sublegal-immature-sized green urchin were 30.9 ± 0.4 and 2.5 ± 0.2 g, respectively (Table 17). The total biomass of green sea urchins at Stephenson Islets in November, 2000 was 92.78 ± 12.73 t, of which 42.63 ± 4.98 t were legal-sized, 49.75 ± 11.71 t were sublegal-mature-sized, and 0.39 ± 0.12 t were sublegal-immature-sized (Table 22).

There were 158,944 ± 14,204 green sea urchins in total (60,331 ± 6,123 legal-sized, 86,056 ± 13,931 sublegal-mature, and 12,556 ± 2,817 of a sublegal-immature size) at Stubbs Island in November, 2000 (Table 22). Based on the TD-total wet weight relationship calculated for all sites combined (Fig. 26), the mean weight per legal-sized green urchin was 84.8 ± 1.9 g (Table 17). The mean weights per sublegal-mature and sublegal-immature green urchin were 36.8 ± 0.8 g and 3.6 ± 0.3 g, respectively (Table 17). The total biomass was calculated as 8.33 ± 0.73 t, of which 5.12 ± 0.52 t, 3.16 ± 0.51 t, and 0.05 ± 0.01 t were comprised of legal, sublegal-mature and sublegal-immature urchins, respectively (Table 22).

At the Plumper Islands survey site on November 5, 2000, there were 1,101,771 ± 208,430 green sea urchins (380,481 ± 112,809 legal-sized, 665,390 ± 101,081 sublegal-mature, and 55,900 ± 9,570 sublegal-immature; Table 22). The mean weights per legal-sized, sublegal-mature-sized and sublegal-immature green urchin were 78.8 ± 1.5, 27.7 ± 0.8, and 4.1 ± 0.3 g (Table 17), based on the TD versus total wet weight relationship calculated for all of the sites combined in November, 2000 (Fig. 26). The total biomass was 48.64 ± 9.33 t, of which 29.97 ± 8.90 t was legal-sized, 18.44 ± 2.82 t was of sublegal-mature size, and 0.23 ± 0.04 t was sublegal-immature green urchins (Table 22).

(d) NOVEMBER 4-6, 2001 SURVEY

There were ten transect lines surveyed at the Stephenson Islets (Fig. 1b), four transects at Stubbs Island (Fig. 1c), and four transects in the Plumper Islands (Fig. 1c; Table 1).

Size: There were 565 quadrats measured and 65 quadrats that were only counted, for a total of 630 quadrats from all sites in this survey. There were 4,077 green urchins counted in total, of which 3,612 were measured (Table 2). After adjusting for unmeasured urchins, as described previously, there were 1,510 (38.7%) legal-sized, 2,412 (57.8%) sublegal-mature-sized, and 155 sublegal-immature green urchins. Fig. 30a shows the size frequency distribution of all measured urchins from all sites combined in the November, 2001 survey. The "Mix3aa" software that uses the Quasi-Newton algorithm showed that the best fit ($X^2 = 206.0$; df = 35; $p < 0.0001$; Table 3) was two dominant modes, one at 44 mm (60%) and the other at 55 mm (40%). The mean TD's and weights for urchins from all of the sites combined were 61.4 ± 0.1 mm and 83.9 ± 0.6 g for legal-sized urchins, 43.0 ± 0.2 mm and 32.5 ± 0.3 g for sublegal-mature urchins, and 18.7 ± 0.4 mm and 3.30 ± 0.2 g for sublegal-immature green urchins (Table 23).

Density: The mean overall total density for all sites combined in this survey was 6.47 ± 0.69 green urchins/m^2 (Table 24). After adjusting for unmeasured urchins, the overall mean densities were 2.40 ± 0.43 urchins/m^2 for legal-sized urchins, 3.83 ± 0.56 urchins/m^2 for sublegal-mature urchins and 0.23 ± 0.06 urchins/m^2 for sublegal-immature urchins.

Depth: The highest mean legal densities (4.41 and 4.42 urchins/m^2) occurred between 0.3 to 3.0 m (1 to 10 ft) below CD, while the highest mean sublegal density (9.89 urchins/m^2) occurred between 1.2 m (4 ft) above CD and zero CD. The highest mean total densities (12.79 ± 3.99 and 11.39 ± 1.43 urchins/m^2) occurred between 1.2 m (4 ft) above CD to 1.5 m (5 ft) below CD (Table 25a; Fig. 31a). In general, the densities gradually decreased above and below those depths, except the density increased to a mid-range value (5.27 ± 0.89 urchins/m^2) in the deepest depth range sampled (i.e., 9.4 to 10.7 m or 31 to 35 ft below CD).

Substrate: Unfortunately, just under half of the quadrats (303) did not have substrate recorded (Table 26a). Of the quadrats with recorded data, creviced bedrock was the substrate most frequently sampled (152 quadrats). There were a few substrate types with very low sampling frequency (1 to 4 quadrats) with very high densities. For example, boulders with creviced bedrock had the highest density (44.50 urchins/m^2; 2 quadrats), followed by creviced bedrock with boulders and cobble (38.0 urchins/m^2; 1 quadrat), then smooth bedrock with cobble and shell (30.00 urchins/m^2, all sublegal; 1 quadrat), and smooth bedrock with creviced bedrock (25.25 urchins/m^2; Table 26a and Fig. 32a). The main substrate type with the highest density (10.55 ± 2.24 urchins/m^2) was cobble, while sand had no urchins present (1 quadrat).

(i) Stephenson Islets

Size: There were 435 quadrats sampled at the Stephenson Islets, of which 38 were not measured, and there was a total of 2,586 green urchins recorded, of which all were measured but 155 (Table 2). After adjusting for unmeasured urchins, there were 783 legal (30.3%), 1,682 (65.0%) sublegal-mature, and 121 (4.7%) sublegal-immature green sea urchins at this site. The size frequency distribution is presented in Fig. 30b. The size frequency analysis showed that two main modes had the best fit ($X^2 = 136.1$; $df = 33$; $p < 0.0001$; Table 3). The first mode was at 43 mm and had a proportion of 56%, while the second mode was at 52 mm, with a proportion of 44%. Mean TD's and total weights for green urchins at Stephenson Islets in November, 2001 were 60.4 ± 0.2 mm and 79.6 ± 0.7 g for legal-sized urchins, 43.3 ± 0.2 mm and 32.7 ± 0.3 g for sublegal-mature urchins, and 18.3 ± 0.5 mm and 3.2 ± 0.2 g for sublegal-immature urchins (Table 23).

Density: The overall mean density for the Stephenson Islets was 5.94 ± 0.83 urchins/m^2 (Table 24). This consisted of (after adjusting for unmeasured urchins) 1.80 ± 0.39 legal-sized urchins/m^2, 3.87 ± 0.80 sublegal-mature urchins/m^2, and 0.26 ± 0.08 sublegal-immature urchins/m^2. The highest total density (11.54 urchins/m^2) occurred on Transect 6, where the highest sublegal-mature density (7.92 urchins/m^2) also occurred. The highest legal density (4.81 urchins/m^2) occurred on Transect 11, while the highest sublegal-immature density (0.56 urchins/m^2) occurred on Transect 9.

Depth: The results are similar to the overall (all sites combined) results. The highest total densities (14.00 ± 5.67 and 11.70 ± 1.95 urchins/m^2) occurred between 1.2 m (4 ft) above CD and 1.5 m (5 ft) below CD (Table 25b; Fig. 31b). The highest legal-sized density (3.92 urchins/m^2)

occurred 1.8 to 3.0 m (6 to 10 ft) below CD, and the highest sublegal-sized density (11.15 urchins/m^2) were observed between 1.2 m (4 ft) and zero CD.

Substrate: Of all the sampled quadrats, 59% did not have data recorded for substrate type. Of the quadrats that did have data, the highest total (all sizes combined) density (30.00 urchins/m^2) occurred on smooth bedrock with cobble and shell, and consisted entirely of sublegal-sized urchins (Table 26b; Fig. 32b). The highest legal-sized urchin density (3.80 urchins/m^2) occurred on boulders with cobble. Creviced bedrock was the main substrate with the highest total density (9.99 urchins/m^2).

(ii) Stubbs Island

Size: Stubbs Island had 86 quadrats sampled during the November, 2001 survey, of which 78 were measured. After adjusting for unmeasured urchins, there were 450 (56.3%) legal-sized, 351 (42.2%) sublegal-mature, and 11 (1.5%) sublegal-immature sized urchins, for a total of 812 urchins (Table 2). The size frequency distribution is presented in Fig. 30c, and the size frequency distribution analysis is shown in Table 3. Two main modes at 30 mm (16%) and 57 mm (84%) gave the best fit ($X^2 = 76.8$; df = 34; $p < 0.0001$). Mean TD's and weights for green sea urchins at Stubbs Island during November, 2001 were 62.8 ± 0.3 mm and 89.6 ± 1.3 g for legal-sized urchins, 43.0 ± 0.5 mm and 33.1 ± 0.9 g for sublegal-mature urchins, and 19.6 ± 1.6 mm and 3.7 ± 0.6 g for sublegal-immature urchins (Table 23).

Density: The mean densities for urchins at Stubbs Island (after adjusting for unmeasured urchins) were 5.23 ± 1.20 for legal-sized, 4.08 ± 0.90 for sublegal-mature, and 0.14 ± 0.03 for sublegal-immature urchins, and 9.44 ± 1.65 for all urchins combined (Table 24). The highest total density (13.44 urchins/m^2) occurred on Transect 16, while the lowest total density (3.83 urchins/m^2) occurred on Transect 18.

Depth: The highest total densities (13.11 ± 5.23 urchins/m^2 to 17.69 ± 2.43 urchins/m^2) occurred in the three shallowest depth ranges (0.9 m or 3 ft above CD to 3.0 m or 10 ft below CD; Table 25c and Fig. 31c). The highest legal density (10.06 urchins/m^2) occurred between 0.3 to 1.5 m (1 to 5 ft) below CD, while the sublegal density was highest (8.78 urchins/m^2) between 0.9 m (3 ft) above CD and zero CD. As at other sites and in past surveys, the general trend was that the densities decreased with depth.

Substrate: The highest total density of green urchins (44.50 urchins/m^2) occurred on boulders with creviced bedrock and was comprised of 26.00 urchins/m^2 of legal-sized urchins (the highest density of legal-sized urchins) and 18.50 urchins/m^2 of sublegal urchins (Table 26c; Fig. 32c). Creviced bedrock with boulders and cobble had the second highest total density (38.00 urchins/m^2), and consisted of 12.00 legal urchins/m^2 and 26.00 sublegal urchins/m^2 (the highest density of sublegal-sized green urchins). The main substrate with the highest total density (22.00 ± 6.47 urchins/m^2; 7 quadrats) was boulders.

(iii) Plumper Islands

Size: There were 90 measured quadrats, and 19 quadrats that were just counted, for a total of 109 quadrats that were sampled at the Plumper Islands. There were a total of 679 green urchins sampled, of which 466 were measured (Table 2). After adjustments for unmeasured urchins, it was estimated that this total consisted of 300 (44.2%) legal-sized, 360 (53.0%) sublegal-mature, and 19 (2.8%) sublegal-immature green urchins in total. The size frequency distribution for the Plumper Islands best fits two modes ($X^2 = 53.1$; df = 28; $p = 0.0028$; Table 3; Fig. 30d). The mean test diameters occurred at 30 and 56 mm, with proportions of 23% and 77%, respectively. Mean TD's and weights of green urchins at the Plumper Islands in November, 2001 were 62.7 ± 0.4 mm and 88.8 ± 1.70 g for legal-sized urchins, 41.4 ± 0.6 mm and 30.2 ± 1.0 g for sublegal-sized urchins, and 21.0 ± 0.7 mm and 4.1 ± 0.3 g for sublegal-immature-sized urchins (Table 23).

Density: The mean total density at the Plumper Islands was 6.23 ± 1.56 urchins/m^2 (Table 24). There was a mean density of 2.75 ± 0.96 urchins/m^2 for legal-sized urchins, 3.30 ± 0.64 urchins/m^2 for sublegal-mature urchins, and 0.15 ± 0.07 urchins/m^2 for sublegal-immature urchins. Transect 20 had the highest total density (9.30 urchins/m^2) as well as the highest legal density (4.92 urchins/m^2) and highest sublegal-mature density (4.24 urchins/m^2). Transect 22 had the highest density of sublegal-immature urchins (0.34 urchins/m^2). The lowest densities for all size categories occurred at Transect 23.

Depth: The highest total density (10.80 ± 2.84 urchins/m^2) and sublegal density (6.13 urchins/m^2) occurred between 3.3 and 4.8 m (11 and 15 ft) below CD, while the highest legal densities (4.67 and 4.86 urchins/m^2) occurred between 3.3 and 6.1 m (11 and 20 ft) below CD (Table 25d; Fig. 31d). The lowest legal (1.08 urchins/m^2), sublegal (0.75 urchins/m^2), and total (1.83 ± 0.73 urchins/m^2) densities all occurred in the 0.3 to 1.5 m (1 to 5 ft) below CD depth range.

Substrate: The highest total density (49.00 urchins/m^2) occurred on smooth bedrock with creviced bedrock, but there was only one quadrat sampled in this substrate mixture, and all of the urchins were unmeasured (Table 26d; Fig. 32d). The highest legal density (12.50 urchins/m^2) occurred on smooth bedrock with cobble (also the second highest total density (23.00 urchins/m^2)), and the highest sublegal density (8.00 urchins/m^2) occurred on boulders with cobble. Cobble was the main substrate with the total highest density (11.10 ± 2.40 urchins/m^2).

(iv) Dissection Data

A random sample of 167 green urchins were collected from all three sites, and were measured, weighed and sampled for roe quality in the lab (Table 27). Legal-sized urchins randomly selected from Stubbs Island had the largest mean values for all of the measurements taken, as compared to legal urchins from the other two sites. Conversely, the legal-sized urchins randomly sampled from the Stephenson Islets had the smallest mean values for all of the measurements taken, except for the mean stomach content weight, which was the smallest for the samples from the Plumper Islands.

A test for homogeneity showed no significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log transformation (to approximate normality) of the total wet weight for each of the three sites separately (F value = 1.40 with df = 2, 163 and $p > 0.05$). This allowed the allometric equation ($W = \alpha TD^{\beta}$) to be used for all sites in the November, 2001 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters) (Figs. 33 and 34), TD (in millimeters) and total wet weight (in grams) (Figs. 35 and 36), and TD (in millimeters) and gonad weight (in grams) (Figs. 37 and 38), for all sites combined and for each of the three sites separately, using EXCEL (see figures for equations).

Legal-sized green urchins randomly collected from the Plumper Islands had the highest percentage (50.0%) of the best quality roe (i.e., orange/yellow colour and firm texture), followed by the Stephenson Islets (43.5%) and then Stubbs Island (40.0%; Table 9). The mean roe recovery rate (total gonad weight (all grades) divided by the total drained weight of all urchins collected) for legal-sized urchins was highest at Stubbs Island (21.1%), second highest at the Plumper Islands (20.0%), and lowest at the Stephenson Islets (16.0%).

(v) Biomass Estimates

There were 2,884,430 ± 400,732 green sea urchins of all sizes at the Stephenson Islets on November 6, 2001 (Table 28). This was calculated by extrapolating the total mean density (6.47 urchins/m^2; Table 24) over the area of Stephenson Islets. There were 873,360 ± 191,204 of legal size, 1,876,107 ± 386,510 of sublegal-mature size, and 134,964 ± 36,883 of an immature size. Using the TD-weight relationship for all sites combined (Fig. 35, since the test for homogeneity described in the previous section showed that there was no significant difference between the slopes for all three sites), mean individual weights were calculated for each size class at each site in November, 2001. The mean weights per legal-sized, sublegal-mature-sized and sublegal-immature-sized green urchin were 79.6 ± 0.7 g, 32.7 ± 0.3 g and 3.2 ± 0.2 g, respectively (Table 23). These weights were multiplied with the abundances to calculate that the biomasses of legal-sized, sublegal-mature-sized, and sublegal-immature-sized green sea urchins at Stephenson Islets in November, 2001 were 69.55 ± 15.23, 61.43 ± 12.66, and 0.43 ± 0.12 t, respectively, for a total biomass of 131.40 ± 19.81 t (Table 28).

At Stubbs Island on November 6, 2001, there was a total of 185,060 ± 32,365 green sea urchins (102,558 ± 23,530 legal-sized, 79,995 ± 17,724 sublegal-mature, and 2,507 ± 503 of an immature size; Table 28). Based on the TD-total wet weight relationship for all sites combined (Fig. 35), the mean weight per legal-sized green urchin was 89.6 ± 1.3 g (Table 23). The mean weights per sublegal-mature and sublegal-immature green urchin were 33.1 ± 0.9 g and 3.7 ± 0.6 g, respectively (Table 23). The biomasses of legal, sublegal-mature and sublegal-immature urchins at Stubbs Island were 9.19 ± 2.11 t, 2.65 ± 0.59 t, and 0.01 ± 0.002 t, respectively, for an overall total biomass of 11.85 ± 2.19 t (Table 28).

At the Plumper Islands survey site on November 6, 2001, there were 1,392,884 ± 347,912 green sea urchins (615,413 ± 214,809 legal-sized, 738,495 ± 142,477 sublegal-mature, and

38,976 ± 16,423 sublegal-immature; Table 28). Based on the TD versus total wet weight relationship for all sites combined in November, 2001 (Fig. 35), the mean weights per legal-sized, sublegal-mature-sized and sublegal-immature green urchin were 88.8 ± 1.7, 30.2 ± 1.0, and 4.1 ± 0.3 g (Table 23). The total biomass was 77.05 ± 19.57 t, of which 54.63 ± 19.09 t was legal-sized, 22.26 ± 4.32 t was of sublegal-mature size, and 0.16 ± 0.07 t was sublegal-immature green urchins (Table 28).

(e) OCTOBER 25-27, 2002 SURVEY

There were ten transect lines surveyed at the Stephenson Islets (Fig. 1b), three transects at Stubbs Island (Fig. 1c), and four transects in the Plumper Islands (Fig. 1c; Table 1).

Size: There were 623 quadrats surveyed in total, of which 416 were measured. Of the total 4,400 green urchins observed during this survey, 1,691 (38.4%) were legal-sized, 2,602 (59.1%) were sublegal-mature, and 107 (2.4%) were sublegal-immature (after adjustments for unmeasured urchins; Table 2). The size frequency distribution is shown in Fig. 39a, and the size frequency analysis is presented in Table 3. There was only one dominant mode (51 mm) for all of the sites combined ($X^2 = 200.0$; df = 38; $p < 0.0001$). The mean TD's and total wet weights for all sites combined were 62.0 ± 0.2 mm and 82.8 ± 0.7 g for legal-sized urchins, 44.6 ± 0.2 mm and 33.9 ± 0.3 g for sublegal-mature urchins, and 17.3 ± 0.8 mm and 2.9 ± 0.3 g for sublegal-immature urchins (Table 29).

Density: The total mean density for all sites combined in October, 2002 was 7.06 ± 0.91 urchins/m^2 (Table 30). The mean overall densities (after adjustment for unmeasured urchins) were 2.71 ± 0.37 urchins/m^2 for legal-sized urchins, 4.18 ± 0.78 urchins/m^2 for sublegal-mature urchins, and 0.17 ± 0.04 urchins/m^2 for sublegal-immature green urchins (Table 30).

Depth: The highest mean total density for all sites combined (13.82 ± 1.63 urchins/m^2) occurred in a depth range of 0.3 to1.5 m (1 to 5 ft) below CD (Table 31a; Fig. 40a). This was also the depth range where the highest legal (6.49 urchins/m^2) and sublegal (7.32 urchins/m^2) densities occurred. The densities above and below this depth range increasingly decreased.

Substrate: The highest total densities for all sites combined (50.00 and 36.00 urchins/m^2) occurred on substrates of cobble with creviced bedrock, and of boulders with cobble and gravel, respectively (Table 32a; Fig. 41a; one quadrat each only). These substrates are also where the highest legal (12.00 and 24.00 urchins/m^2, respectively) and sublegal (38.00 and 12.00 urchins/m^2, respectively) densities occurred. Cobble was the main substrate with the highest total density.

(i) Stephenson Islets

Size: There were 3,457 green urchins from 451 quadrats surveyed in the Stephenson Islets in October, 2002, of which 1,806 were measured (from 257 quadrats; Table 2). The total was comprised of (after adjusting for unmeasured urchins) 1,122 (32.5%) legal-sized urchins, 2,240 (64.8%) sublegal-mature urchins, and 95 (2.8%) sublegal-immature urchins. The analysis of the size frequency distribution (Fig. 39b and Table 3) showed there was one dominant mode at 48 mm ($X^2 = 183.4$; df = 34; $p < 0.0001$). Mean TD's and total wet weights for urchins from Stephenson

Islets were 60.3 ± 0.2 mm and 71.8 ± 0.7 g for legal-sized green urchins, 44.3 ± 0.2 mm and 31.8 ± 0.4 g for sublegal-mature urchins, and 17.5 ± 0.9 mm and 2.9 ± 0.3 g for sublegal-immature urchins (Table 29).

Density: After adjusting for the unmeasured urchins, the mean total, legal, sublegal-mature and sublegal-immature densities at the Stephenson Islets were 7.67 ± 1.14 urchins/m^2, 2.49 ± 0.42 urchins/m^2, 4.97 ± 0.96 urchins/m^2 and 0.21 ± 0.05 urchins/m^2, respectively (Table 30). The highest total densities occurred at Transects 9 (12.80 urchins/m^2) and 13 (11.59 urchins/m^2), and the lowest total density (1.76 urchins/m^2) occurred at Transect 10 (Table 30). The highest legal densities (after adjusting for unmeasured urchins) occurred at Transects 11 (4.19 urchins/m^2) and 13 (4.14 urchins/m^2). The highest sublegal-mature density (9.77 urchins/m^2 after adjustment) was observed at Transect 9, and the highest sublegal-immature density (0.51 urchins/m^2 after adjustment) occurred at Transect 13.

Depth: The highest mean total (15.53 ± 2.26 urchins/m^2), legal (5.76 urchins/m^2), and sublegal (9.78 urchins/m^2) densities all occurred in the 0.3 to 1.5 m (1 to 5 ft) below CD depth range (n=58 quadrats; Table 31b; Fig. 40b). The densities below this depth range gradually decreased with each depth increment.

Substrate: The most frequently surveyed substrate was creviced bedrock (175 quadrats), followed by smooth bedrock (145 quadrats; Table 32b and Fig. 41b). The highest total (50.00 urchins/m^2), legal (12.00 urchins/m^2) and sublegal (38.00 urchins/m^2) densities occurred on cobble with creviced bedrock, however only one quadrat of this substrate was surveyed. Cobble was the main substrate with the highest overall density (9.63 urchins/m^2); however, it also had a very large standard deviation (due to the one quadrat mentioned above).

(ii) Stubbs Island

Size: There were 66 quadrats surveyed at Stubbs Island, from which a total of 538 green urchins were measured (Table 2). This included 321 (59.7%) legal-sized, 210 (39.0%) sublegal-mature, and 7 (1.3%) sublegal-immature urchins. The analysis of the size frequency distribution (Table 3 and Fig. 39c) showed that there was one main frequency mode at 56 mm ($X^2 = 81.2$; df = 36; $p < 0.0001$). Mean TD's and total wet weights of urchins at Stubbs Island in October, 2002 were: 64.7 ± 0.4 mm and 98.7 ± 1.7 g for legal-sized urchins; 44.5 ± 0.5 mm and 35.5 ± 0.9 g for sublegal-mature urchins; and 18.3 ± 1.9 mm and 3.1 ± 0.8 g for sublegal-immature urchins (Table 29).

Density: The overall mean total, legal, sublegal-mature and sublegal-immature densities at Stubbs Island were 8.15 ± 1.24 urchins/m^2, 4.86 ± 0.96 urchins/m^2, 3.18 ± 1.09 urchins/m^2 and 0.11 ± 0.01 urchins/m^2, respectively (Table 30). The highest densities at Stubbs Island usually occur at Transect 15, however it was not surveyed this year due to current and timing restrictions. During this survey, the highest mean total (10.19 urchins/m^2), legal (7.50 urchins/m^2) and sublegal-immature (0.13 urchins/m^2) densities occurred at Transect 16, and the lowest densities for all size categories occurred at Transect 18.

Depth: The highest total (18.08 ± 1.68 urchins/m^2), legal (11.08 urchins/m^2) and sublegal (7.00 urchins/m^2) densities all occurred in the 0.3 to 1.5 m (1 to 5 ft) below CD depth range (Table 31c; Fig. 40c). As observed in other surveys and at other sites, the densities decreased with each depth interval above and below this range.

Substrate: At Stubbs Island, the substrate most frequently surveyed was smooth bedrock (31 quadrats, Table 32c). The highest mean total (36.00 urchins/m^2), legal (24.00 urchins/m^2) and sublegal (12.00 urchins/m^2) densities all occurred on a substrate of boulders with cobble and gravel (one quadrat only; Table 32c and Fig. 41c). The main substrate with the highest total density (11.24 ± 2.51 urchins/m^2) was boulders.

(iii) Plumper Islands

Size: During the October, 2002 survey there were a total of 106 quadrats surveyed in the Plumper Islands, of which 93 had measurements recorded. There were 405 green urchins measured, of which (after adjusting for unmeasured urchins) there were 248 (61.2%) legal-sized urchins, 152 (37.5%) sublegal-mature urchins, and 5 (1.2%) sublegal-immature urchins (Table 2). The size frequency distribution is presented in Fig. 39d, and Table 3 presents the results of the test diameter frequency analysis. As observed at other sites during this survey, there was one main frequency mode, this time occurring at 55 mm ($X^2 = 115.1$; df = 34; $p < 0.0001$). The mean TD's and total wet weights for legal, sublegal-mature and sublegal-immature-sized urchins were 62.5 ± 0.4 mm and 88.5 ± 1.6 g, 46.2 ± 0.5 mm and 38.3 ± 0.9 g, and 14.2 ± 2.4 mm and 1.8 ± 0.9 g, respectively (Table 29).

Density: The mean densities at the Plumper Islands in October, 2002 (after adjusting for unmeasured urchins) were 3.82 ± 1.34 urchins/m^2 for all size categories combined (total), 2.34 ± 1.00 urchins/m^2 for legal-sized urchins, 1.43 ± 0.42 urchins/m^2 for sublegal-mature urchins, and 0.05 ± 0.03 urchins/m^2 for sublegal-immature urchins (Table 30). The highest total (6.87 urchins/m^2) and legal (4.81 urchins/m^2) densities occurred at Transect 22, whereas the highest sublegal-mature density (2.06 urchins/m^2) occurred at Transect 20 and the highest sublegal-immature density (0.20 urchins/m^2) occurred at Transect 23.

Depth: The highest total (11.71 ± 2.87 urchins/m^2) and sublegal (7.00 urchins/m^2) densities occurred in a depth range of 0.0 to 0.9 m (0 to 3 ft) above CD (Table 31d; Fig. 40d). There was not the gradual decrease in density with each increment of depth as observed in most other surveys and sites, but rather an alternating decrease/increase with each depth range (Table 31d).

Substrate: Smooth bedrock was surveyed the most frequently in the Plumper Islands (54 quadrats; Table 32d). The highest total (7.33 urchins/m^2) density occurred on a substrate of smooth bedrock with cobble and shell (Fig. 41d). The highest sublegal density (6.00 urchins/m^2) also occurred on this substrate as well as on creviced bedrock with cobble. The highest legal density (3.73 urchins/m^2) occurred on creviced bedrock. The main substrate with the highest total density (5.03 ± 1.62 urchins/m^2) was boulders.

(iv) Dissection Data

Lab measurements were taken slightly different during this survey. There were 139 green sea urchins that were randomly collected from all locations and fully measured and analyzed in the same method as in all the other surveys (Table 33). In addition, there were an extra 181 urchins (in total) that were collected from all of the sites that only had their test heights, test diameters and total wet weights measured. Therefore there are two sample sizes presented in Table 33. These additional measurements were taken in order to calculate a more accurate test diameter/wet weight relationship (i.e. providing a larger sample size, without spending an inordinate amount of time with all of the other measurements).

The legal-sized urchins randomly selected from Stubbs Island (n=30) had the largest mean measurements for all of the lab measurements taken, except for the mean stomach and content weight (Table 33), which was largest for legal-sized urchins from the Plumper Islands. In contrast, legal-sized urchins randomly selected from the Stephenson Islets (n=90) had the smallest mean measurements. These results were the same as the field survey data results, where the mean legal test diameters and total wet weights were largest for green urchins measured at Stubbs Island and smallest for urchins measured at the Stephenson Islets (Table 29).

A test for homogeneity showed there was a significant difference between the slopes of the regression lines for the relationship between test diameter and the natural log transformation (to approximate normality) of the total wet weight for the three separate sites (F value = 4.50 with df = 2, 317 and $p > 0.05$). Therefore individual allometric equations $(W=\alpha TD^{\beta})$ were used for each site in the October, 2002 survey when calculating the total wet weight (in grams) from the TD (in millimeters).

The best (i.e., highest R^2) power relationships were calculated between TD (in millimeters) and test heights (in millimeters) (Figs. 42 and 43), TD (in millimeters) and total wet weight (in grams) (Figs. 44 and 45), and TD (in millimeters) and gonad weight (in grams) (Figs. 46 and 47), for all sites combined and for each of the three sites separately, using EXCEL (see figures for equations).

Legal-sized green urchins from all of the sites had some of the highest percentages of the best quality roe (i.e., orange/yellow colour and firm texture) observed since the surveys first began, with legal urchins from the Plumper Islands with the highest (86.7%), followed by the Stephenson Islets (77.5%) and lastly, Stubbs Island (71.4%; Table 9). However, the mean roe recovery rates (total gonad weight (all grades) divided by the total drained weight of all urchins sampled) are some of the lowest over all the surveys. The highest mean roe recovery rate for legal-sized urchins occurred at the Stephenson Islets (17.9%), followed by the Plumper Islands (17.4%), and then Stubbs Island (17.2%).

(v) Biomass Estimates

The mean total density at the Stephenson Islets in October, 2002 (7.67 urchins/m^2; Table 30) was extrapolated over the total area between zero and 10 m below CD (485,200 m^2), to derive there were 3,719,149 ± 554,667 green sea urchins of all sizes at this site (Table 34). This included 1,207,083 ± 204,958 legal-sized, 2,409,863 ± 463,376 sublegal-mature, and 102,204 ± 23,660 sublegal-immature green urchins. Since a test for homogeneity showed there was a significant difference between the slopes of the TD-total wet weight regressions for the three sites, the TD-total wet weight relationship from the dissection data for all urchins collected only from the Stephenson Islets in October, 2002 (Fig. 45a) was applied to all the test measurements recorded in the field for the Stephenson Islets. Mean individual wet weights were then calculated for the three size classes. The mean weights per legal-sized, sublegal-mature-sized and sublegal-immature-sized green sea urchin from Stephenson Islets were determined to be 71.8 ± 0.7 g, 31.8 ± 0.4 g, and 2.9 ± 0.3 g, respectively (Table 29). Multiplying the individual weights with the abundances gave total biomasses of 86.72 ± 14.73 t, 76.65 ± 14.75 t, and 0.29 ± 0.07 t for legal-sized, sublegal-mature and sublegal-immature green sea urchins at Stephenson Islets in October, 2002 (Table 34). The overall total biomass was 163.65 ± 20.85 t.

By extrapolating the mean densities (Table 30) over the total area at Stubbs Island, it was determined that there was a total of 59,770 ± 24,237 green urchins, of which 95,327 ± 18,846 were of legal size, 62,364 ± 21,340 that were sublegal-mature, and 2,079 ± 136 that were sublegal-immature (Table 34). The mean individual wet weights, calculated using the TD-total wet weight relationship for Stubbs Island urchins only (Fig. 45b), were 98.7 ± 1.7 g, 35.5 ± 0.9 g, and 3.1 ± 0.8 g for legal-sized, sublegal-mature-sized, and sublegal-immature green urchins, respectively (Table 29). The total biomass at Stubbs Island in October, 2002 was 11.63 ± 2.01 t (Table 34). This was comprised of 9.41 ± 1.86 t of legal-sized urchins, 2.21 ± 0.76 of sublegal-mature urchins, and 0.01 ± 0.001 t of sublegal-immature urchins.

The estimated numbers of green urchins in the Plumper Islands survey site in October, 2002, based on the calculated mean densities (Table 30), were 523,140 ± 223,440 legal-sized urchins, 320,634 ± 93,290 sublegal-mature urchins, and 10,547 ± 7,543 sublegal-immature urchins, for a total of 854,321 ± 276,504 green urchins (Table 34). The mean individual wet weights were calculated using the TD-total wet weight relationship for Plumper Island urchins only (Fig. 45c). They were 88.5 ± 1.6 g, 38.3 ± 0.9 g, and 1.8 ± 0.9 g for legal-sized, sublegal-mature, and sublegal-immature urchins, respectively (Table 29). The biomass estimates were 46.27 ± 19.78 t of legal-sized urchins, 12.26 ± 3.58 t of sublegal-mature urchins, and 0.02 ± 0.02 t of sublegal-immature urchins, for a total biomass estimate of 58.55 ± 20.10 t (Table 34).

(f) THE FISHERY

The British Columbia green sea urchin fishery started in 1987, and has had many management restrictions placed on it as it has developed over the years. Restrictions in the number of licences and of harvesting techniques (hand-picking by divers only), a minimum size limit of 55 mm, Management Area closures, area quotas, Individual Vessel Quotas (IVQ's), and fishing seasons are all controls that managers have put in place to regulate this fishery. During the 1998/99 fishing season, Areas 11, 12, 13, 17, 18, 19, 20 and 28 in the South Coast were open to commercial fishing, but Areas 17 and 28 were subsequently closed for all the following seasons (to present) due to conservation concerns. Table 35 outlines the details of the commercial green sea urchin fishery over the five seasons that these surveys covered. The table includes the opening and closing dates for the fishery, the closing date for Area 12 (i.e., when the quota was attained from the management area where the surveys were undertaken), the amount of product harvested from the Stephenson Islets during the fishing season (as recorded in the harvest logbook records, $B_{fishing}$), and the percentage of harvest that the Stephenson Islets represented of the total harvest from Area 12. Starting in the 2001-2002 fishing season, the international market began to change, causing a large effect on the B.C. green urchin fishery. There has been an oversupply of green sea urchins on the Japanese market, primarily supplied from Russia, which has caused the global price of green urchins to drop dramatically. The Japanese buyers have not been as interested in buying green urchins from B.C. because they have been able to get more than enough of their supply from Russia for a lower price. The B.C. processors have only been able to sell to Japan when the weather has been too rough for the Russian packers to travel (D & D Pacific Fisheries Ltd. 2002). As a result, only 68% of the fishery's total allowable catch (TAC) was harvested in the 2001-2002 fishing season, and 80% of the TAC was harvested in the 2002-2003 fishing season (D & D Pacific Fisheries Ltd. 2003). The amount harvested from the Stephenson Islets was lowest in the 2002-2003 fishery, mainly because certain fishers that normally fish the Stephenson Islets did not fish this particular season (Table 35).

It should be noted that due to misunderstandings about where the research closure boundaries were, one fisher admitted to 'accidentally' harvesting part of the research area in the Plumper Islands in the 1998-1999 fishing season. It is difficult to determine exactly how much was harvested from here, but we estimate it was 1,380 to 3,500 lbs. The amount harvested is irrelevant, as the exact locations where it was removed can not be determined. If the amount was removed exactly in the same locations as the research transects it would affect the density calculations considerably, whereas if it was removed away from the transects, then there would be little effect. The main point is that the density estimates, and consequently the biomass estimates, for the Plumper Islands in the survey following this event (i.e., November, 1999) may be lower than expected.

(g) FISHING EXPLOITATION

The exploitation of green sea urchins from the Stephenson Islets during each fishing season was calculated using equations 5 and 6 in the Methods Section. Basically, the fishing exploitation represents the amount of legal-sized green sea urchins harvested from the Stephenson Islets by the fishing industry over the fishing season, divided by the legal-sized biomass just prior to the opening of the fishery. The results are presented in Table 35. The highest exploitation (0.29 ± 0.03) occurred during the 2000-2001 fishing season, not because a higher than normal amount of green urchins was removed by the fishery, but because the biomass estimate was so low at the start of the season. The lowest exploitation (0.08 ± .002) occurred during the 2002-2003 fishing season because not as many green urchins were harvested in the Stephenson Islets. This was because the price per pound of green urchin roe was low that year due to competition from Russia, and because certain fishers that normally fish the Stephenson Islets did not fish there during that season.

DISCUSSION

(a) SIZE DISTRIBUTION CHANGES

In November, 1998 the percentage of legal-sized urchins was highest at the Stephenson Islets, but it was very close to the percentages at both Stubbs Island and the Plumper Islands during this survey. In all other surveys, the percentage of legal-sized urchins was highest at Stubbs Island, except in October, 2002, when the percentage of legal-sized urchins from the Plumper Islands was the highest. The percentage of legal-sized urchins was lowest in the Plumper Islands for the November, 1998 and 1999 surveys and lowest for the Stephenson Islets for the November, 2000, 2001 and October, 2002 surveys. The fact that green urchins were 'accidentally' harvested from the Plumper Islands survey site in the 1998-1999 fishing season, could explain why there was a very large decrease in the percentage of legal-sized urchins at that location. Since green urchins are harvested annually at the Stephenson Islets, and not (usually) harvested at the other locations, it is reasonable that the percentage of legal-sized urchins is lowest at the Stephenson Islets.

The percentage of sublegal-mature green urchins was highest at Stephenson Islets for all surveys except for November, 1999. This is probably because legal-sized urchins are removed from the Stephenson Islets annually, resulting in a converse increase in the percentage of sublegal-mature urchins. The large percentage of sublegal-mature urchins at the Plumper Islands in November, 1999 is probably due to the legal-sized urchins being harvested from the Plumper Islands by accident during the previous fishing season, thereby decreasing the percentage of legal-sized urchins and resulting in a large, but artificial, increase in the percentage of sublegal-mature urchins. The percentage of sublegal-immature urchins was highest at the Plumper Islands during the November, 1998 and 1999 surveys, highest at Stubbs Island in November, 2000, and highest at the Stephenson Islets in November, 2001 and October, 2002. Surprisingly, the percentage of sublegal-immature urchins consecutively decreased for all locations during each of the five surveys.

The changes in size frequencies between the different surveys and between the three sites are difficult to analyze, as test size is not a reliable index of age. Green sea urchins have discontinuous growth, which fluctuates with the availability and species of vegetation (Himmelman *et al.* 1983, Larson *et al.* 1980, Vadas 1977, Vadas *et al.* 2002). The size frequency analyses revealed that the number of frequency modes for all three sites decreased from November, 1998 to October, 2002. In November, 1998 there were four frequency modes for the Stephenson Islets and three for the Plumper Islands, and the first modes were 8 and 6 mm, respectively. There were two frequency modes for Stubbs Island. For the next three subsequent surveys the number of frequency modes decreased to two for all sites (except four modes were observed at the Plumper Islands in November, 1999), and did not include a mode of the very small urchins from the first settlement season (except for a small percentage (3%) at the Stephenson Islets in November, 2000). There was only one main mode close to the legal size for all of the three survey locations in October, 2002. Urchins in their first year of settlement are very small, can hide in small crevices and amongst the vegetation and can be easily missed, so it is possible that they were present in all surveys but not observed. However, we suspect that this, along with the fact that the percentage of sublegal-immature urchins consecutively decreased for all locations from November, 1998 to October, 2002 (and other information discussed later) indicates there was good recruitment in November, 1998 (a highly successful spawn in the spring of 1998), and poor recruitment for all other following seasons discussed in this report.

(b) LENGTH-WEIGHT RELATIONSHIPS

Test diameters of the green sea urchins were measured in the field, and their associated individual weights were estimated using a "length-weight" regression developed from lab measurements from urchins collected in the field. The mean TD's and total wet weights for legal-sized green urchins measured in the field were largest for urchins from Stubbs Island, second-largest for urchins from the Plumper Islands, and smallest for urchins from the Stephenson Islets for all five surveys (except the TD's and total wet weights in November, 1998 were largest for urchins from the Plumper Islands and second-largest for urchins from Stubbs Island). This is likely because the Stephenson Islets has always been open to fishing since the commercial fishery started, and has been considered a popular commercial fishing location, so larger urchins are more likely to be removed thus lowering the mean size over time. The other locations have been closed for scientific research purposes since 1995. Prior to this, Stubbs Island was considered locally as a "reserve", so green sea urchins were left to continue growing (except for the "accidental harvesting" of a small amount during the 1997-1998 fishing season (Waddell *et al.* 2003)), resulting in more of the larger urchins at this site. The Plumper Islands were commercially fished prior to 1995, and also had 1380 to 3435 lbs "accidentally" harvested in 1998-1999, so because it is recovering from harvesting it has a mixture of "older and larger" legal-sized urchins and "smaller, more recently recruited" legal-sized urchins, making it a site with on average "medium-sized" legal urchins.

The fact that the Stephenson Islets is commercially fished is probably also why the mean legal TD's at the Stephenson Islets did not change very much (maximum 1.3 mm or 2.1% change) between the five surveys, since the larger (and likely older) legal-sized urchins have been previously fished out. However, the mean legal total wet weights at the Stephenson Islets did have a large variation (maximum of 18.1 g) over the five surveys, and generally seemed to be decreasing with time (from 89.9 g in November, 1998 to 71.8 g in October, 2002, a 20.1% decrease). A similar situation occurred at the Plumper Islands where the mean total wet weight of legal-sized urchins was largest in November, 1998 (99.8 g), lowest in November, 2000 (78.8, a 21.0% decrease), and second lowest in October, 2002 (88.5 g, a 11.3% drop from November, 1998. In contrast, the mean legal total wet weights for urchins from Stubbs Island have increased over the five surveys, i.e. they were second lowest in November, 1998 (96.7 g), lowest in November, 2000 (84.8 g, a 12.3% decrease), and highest in October, 2002 (98.7 g, a 2.1% increase over the November, 1998 value).

Sublegal-mature urchins from Stephenson Islets had the largest mean TD in October, 2002, but the largest mean total wet weight in November, 1998. The mean TD's and total wet weights were largest for Stubbs Island urchins in November, 2000 and largest for the Plumper Island urchins in October, 2002. Sublegal-mature urchins from all sites were very small in 1999.

They all had the lowest mean TD's and total wet weights in November, 1999 (except the mean TD for sublegal-mature Stubbs Island urchins was smallest in November, 1998).

The smallest mean sublegal-immature TD and total wet weight for the Stephenson Islets was observed in November, 1998. In this same year, sublegal-immature urchins from the Plumper Islets also had the smallest mean TD (and second smallest total wet weight). This is interesting because the following year, November, 1999, both of these locations had the smallest mean sublegal-mature TD's and total wet weights for all of the five surveys. The smallest mean sublegal-mature total wet weight for Stubbs Island also occurred in November, 1999. In addition, the smallest mean legal-sized TD for the Stephenson Islets, the smallest mean legal-sized total wet weight for Stubbs Island, and the smallest mean legal-sized TD and total wet weight for the Plumper Islands all occurred in November, 2000. This supports the hypothesis that there was a good spawn in the spring of 1998, and good recruitment in the fall of 1998 of sublegal-immature urchins, especially in the Stephenson Islets and the Plumper Islands, which lowered the average size of sublegal-immature urchins (due to large numbers of small animals). This smaller mean size due to recruitment can be traced into the sublegal-mature size category in November, 1999 and into the legal-sized category in November, 2000.

(c) DENSITY

(i) General Changes

The mean density for legal-sized green urchins at Stephenson Islets was the lowest in November, 2000 for the five year study period, and then increased to the highest in October, 2002. In the November, 1997 survey (Waddell *et al.* 2003), one year prior to these five surveys, the density of legal-sized urchins was lower than in any of the surveys discussed in this report. At Stubbs Island and the Plumper Islands, the legal-sized urchins had the highest mean density in November, 2001. The lowest mean legal-sized density was in November, 1998 for urchins from Stubbs Island, and in November, 1999 for the Plumper Islands. The accidental harvesting by a commercial fisher in the research closure area in the Plumper Islands in the 1998-1999 fishing season may be the reason for the very low density of legal-sized green urchins at that location in November, 1999.

At the Stephenson Islets, the mean sublegal-mature density basically increased each year from a low in November, 1998 to the high in October, 2002. In November, 1997 (Waddell *et al.* 2003), the density of sublegal-mature urchins at the Stephenson Islets was even lower than in November, 1998. At Stubbs Island and the Plumper Islands, the mean sublegal-mature densities were lowest in November, 1998, and increased each survey to a high in 2000 for Stubbs Island and 2001 for the Plumper Islands.

The mean densities of sublegal-immature urchins were highest in 1999 for both the Stephenson Islets and Stubbs Island, and then decreased each following year to the lowest mean densities in 2002. The trend was the same for sublegal-immature urchins at Plumper Islands, except that the highest mean density occurred in 1998 and decreased progressively each following year to a low in October, 2002. Although the densities of sublegal-immature urchins were low in October, 2002, the densities were even lower in the November, 1997 survey (Waddell *et al.* 2003). The low mean densities of sublegal-immature urchins in November, 1997, the large increase in November, 1998 at all sites, a slight increase again in November, 1999 at the Stephenson Islets and Stubbs Island, followed by the generally decreasing mean sublegal-immature densities and the increasing mean sublegal-mature and legal-sized densities again supports the hypothesis that there was a good spawn and good recruitment in 1998, a smaller spawn in 1999, and then less successful juvenile recruitment in the following survey years.

The mean total density (all size classes combined) for the Stephenson Islets was highest in 2002, and it was highest for Stubbs Island and the Plumper Islands in 2001. Surprisingly, even though there is no strong evidence that there has been good recruitment over the latter years that the surveys were undertaken, the mean overall total density (i.e., all size classes from all sites combined) has increased steadily each year from 3.31 ± 0.58 in November, 1998 to 7.06 ± 0.91 in October, 2002.

The highest density of legal-sized urchins occurred at the Stephenson Islets in November, 1998, and at Stubbs Island in all following surveys. The highest density of sublegal-mature-sized urchins also occurred in the Stephenson Islets in November, 1998 and at Stubbs Island for every following survey, except for October, 2002, when it was highest for the Stephenson Islets again. Sublegal-immature urchins had the highest density at the Plumper Islands in November, 1998, at Stubbs Island in November, 1999 and 2000, and in the Stephenson Islets in November, 2001 and October, 2002.

(ii) Changes with Depth

In general, green sea urchins in this study area have been in greater density in shallower waters, and have decreased in density with increasing depth. Himmelman (1986) also observed green urchin abundance generally decreased at greater depth. However, there were subtle differences between the sites and size classes in our surveys. Legal-sized green urchins with the highest mean density were usually found in the shallowest waters at Stephenson Islets (0.6 m (2 ft) above CD to 3.0 m (10 ft) below CD), were found consistently between 0.3 to 1.5 m (1 to 5 ft) below CD at Stubbs Island, and were found in the deepest depths (from 1.8 to 12.2 m (6 to 40 ft) below CD) at the Plumper Islands. Sublegal-sized urchins at the Stephenson Islets had the highest mean density between 1.2 m (4 ft) above CD and 4.8 m (15 ft) below CD, and 3 of the 5 surveys had the highest mean density between zero CD and above. Similar results were observed at the Plumper Islands, but 3 of the 5 surveys had the highest mean sublegal densities between 3.3 and 4.8 m (11 and 15 ft). Sublegal-sized green urchins were in highest mean densities at Stubbs Island between 1.2 m (4 ft) above CD and 3.0 m (10 ft) below CD. The highest mean total densities at the Stephenson Islets were observed between 1.2 m (4 ft) above CD and 3.0 m (10 ft) below CD, while at Stubbs Island they were consistently between 0.3 and 1.5 m (1 and 5 ft) below CD for each survey. At the Plumper Islands, the highest mean total densities were observed between 9.4 and 10.7 m (31 and 35 ft) below CD in 1998, then between 3.3 and 4.8 m (11 and 15 ft) below CD for the next three years (1999 to 2001), and between 0.9 m (3 ft) above CD to zero CD in 2002. Vegetation consumed by green urchins is in highest density in shallower waters. Why urchins in the Plumper Islands were observed in highest densities in deeper depth intervals in some years is unknown. Perhaps urchins at this site depend more on drift algae than attached algae.

(iii) Changes with Substrate

The type of substrate where the highest densities of urchins occurred seemed to vary with each survey, at each site, and with each size class. It should be noted that the number of quadrats of each of the substrate types sampled varied at each of the sites between the five surveys. Therefore, part of these differences in substrate preference results may be due to the fact that different divers were involved in the five surveys, and they may have used different criteria for determining between the substrate types, especially between the smooth and creviced bedrock. Also, there were two dive teams for each survey, so again the dive teams may have used different criteria, even though the teams are given guidelines for determining between the substrates. Additionally, as mentioned previously, the transect lines are never repeated exactly between surveys. Regardless, the general trend, not surprisingly, was that green sea urchins were observed more consistently and in higher densities on smooth and creviced bedrock, boulders, cobble and shell, less frequently on gravel or pea gravel, and almost never on sand. Mud was not observed at any of the sites. Differences in densities of green urchins on various substrate types may have nothing to do with substrate type alone, but rather may be more related to whether there are desirable attached algae or drift algae on that substrate. One of their preferred foods, *Nereocystis luetkeana* (bull kelp), can be massive in size when mature, with a long stipe, large bulb and numerous, long blades. It has a strong holdfast that needs a type of substrate that will secure it. Substrates such as sand, mud, shell and pea gravel can not support *Nereocystis luetkeana*.

(d) DISSECTION RESULTS

The mean stomach content weights for legal-sized and sublegal-mature-sized urchins collected from the Stephenson Islets were highest in November, 1998, whereas they were highest for legal-sized and sublegal-mature-sized urchins from the Plumper Islands, as well as for legal-sized urchins from Stubbs Island in October, 2002. Sublegal-mature urchins from Stubbs Island had the highest mean stomach content weight in November, 1999, although this could be due to methodological differences. Stomach and contents were removed and weighed in Nov. 1998, 1999, and Oct. 2002, but only stomach contents were removed and weighed in Nov. 2000 and 2001.

The mean gonad weights were highest in November, 1998 for legal-sized and sublegal-mature urchins collected at all three survey sites. The mean gonad weights for legal-sized urchins were even higher in November, 1997 for all sites (Waddell *et al.* 2003). This may be a reason why juvenile recruitment was so successful in 1998 and why another smaller, but still successful spawn occurred in 1999. The mean gonad weights were lowest in November, 1999 for legal-sized urchins from Stubbs Island and the Plumper Islands and for sublegal-mature urchins from the Plumper Islands and the Stephenson Islets. They were also lowest in weight in November, 2001 for legal-sized urchins from Stephenson Islets and sublegal-sized urchins from Stubbs Island.

The quality of roe varied widely each year. The percentage of legal-sized urchins with the best quality roe (good colour and texture) was highest for urchins collected from Stubbs Island in November, 1998 and 2000, and for urchins from the Plumper Islands in all the other three survey years, whereas urchins from the Stephenson Islets had the lowest or second lowest percentage of best quality roe for all five surveys. The mean roe recovery rates (the percentage of total gonad weights (all grades) divided by the total drained weight of all urchins collected) for legal-sized urchins was highest for urchins collected from Stubbs Island for all surveys (20.2 to 23.0%) except October, 2002, when it was highest for urchins from the Stephenson Islets (17.9%). The mean roe recovery rate for legal-sized urchins from all surveys and locations ranged from 16.0 to 23.0%.

(e) CHANGES IN BIOMASS

The criteria we used to estimate "total area" of green sea urchin habitat for the biomass calculations was all area with a depth between 0 and 10 m below CD. The majority of green urchins are found within this depth range, however, it is realized that they have a wide range in habitable depth, so these are conservative estimates. The area estimates are largest (485,200 m^2) for the Stephenson Islets, so it is not surprising that the biomass estimates are highest here. The area estimate for the Plumper Islands (223,600 m^2) is about half the size as for the Stephenson Islets, and the biomass estimates are always smaller. Stubbs Island has the smallest area estimate (19,600 m^2, only 4% of the area of the Stephenson Islets), and always has a much smaller biomass estimate than the other two sites.

Changes in total legal biomass at the Stephenson Islets between the start and finish of a fishing season can no longer be calculated like in the earlier survey years (Waddell *et al.* 1997, 2002, 2003), as the post-season surveys have been eliminated. However, changes in biomass between years can still be calculated. The total biomass of legal-sized green urchins at the Stephenson Islets site increased from 41.02 t in November, 1997 (Waddell *et al.* 2003) to 76.14 t in November, 1998, after 11.65 t (Table 35) were removed during the 1997-1998 fishing season. This means the legal biomass actually increased by (76.14 + 11.65 - 41.02 =) 46.77 t over that year, a 114% increase. Between November, 1998 and November, 1999, the total legal biomass increased from 76.14 t to 79.22 t after 10.15 t were removed by the fishery (meaning the biomass actually increased by 13.23 t over the year, or a 17% increase). The legal biomass then decreased from 79.22 t in November, 1999 to 42.63 t in November, 2000 after 13.39 t were harvested in the fishery, meaning there was a total decrease of 23.20 t (equivalent to a 71% decrease). However, the biomass for November, 2000 may be underestimated because some transects were incompletely surveyed and others were missed entirely. The total legal biomass increased again between November, 2000 and November, 2001, from 42.63 t to 69.55 t with a 12.17 t removal from the fishery (equivalent to a total change of 39.09 t or 92%). The legal biomass increased again from 69.55 t in November, 2001 to 86.72 t in October, 2002, after 11.30 t were removed by the fishery, equalling a total change of 28.47 t, or 41%. The total legal biomass in October, 2002 at the Stephenson Islets was the highest observed in all of the fall surveys since they began in October, 1995 (Waddell *et al.* 1997, 2002, 2003).

At Stephenson Islets, the biomass of sublegal-mature green urchins also increased with each survey, from 25.65 ± 7.21 t in November, 1997 (Waddell *et al.* 2003) to 76.65 ± 14.75 t in October, 2002, an increase of 51.00 t or almost 200% over the five years of study. The biomass of sublegal-immature urchins at Stephenson Islets increased from 0.11 ± 0.05 t in November, 1997 (Waddell *et al.* 2003) to 0.95 ± 0.13 t in November, 1999 (an increase of 0.84 t or 764%

over two years), but then decreased over the next few years to 0.29 ± 0.07 t in October, 2002 (a decrease of 0.66 t or almost 70% since the peak three years prior). This huge increase in biomass of the sublegal-immature urchins initially, followed by the decline in later years again supports the theory that there was a good spawn and recruitment in 1998, a smaller, less successful spawn in 1999, followed by much lower juvenile recruitment during the span of the remaining survey years. The increase in biomass of sublegal-mature urchins over this study period also helps to support this theory.

The total (all size classes combined) biomass at Stephenson Islets (after fishing) has increased steadily each year (except for a decrease in November, 2000) from 66.78 ± 10.56 t in November, 1997 (Waddell *et al.* 2003) to 163.65 ± 20.85 t in October, 2002, an increase of 96.87 t or 145%. The actual increase is greater than this because we have not taken into account the biomass of legal-sized urchins removed by the fishery each year.

The biomass of legal-sized urchins at Stubbs Island has fluctuated over the five year study period, but has had an overall increase from 4.07 ± 1.27 t in November, 1997 (Waddell *et al.* 2003) to 9.41 ±1.86 t in October, 2002, a 5.34 t or 131% increase. The biomasses of both the sublegal-mature and sublegal-immature urchins at Stubbs Island increased from November, 1997 to November, 2000, and then decreased again over the two following years. The biomass of sublegal-immature urchins at Stubbs Island was the same in October, 2002 as it was in November, 1997.

The biomass of legal-sized urchins in the Plumper Islands has also fluctuated over the five year study period. The biomass of legal-sized urchins in the Plumper Islands in November, 1997 was 6.29 ± 2.23 t (Waddell *et al.* 2003). The following year the biomass increased to 20.68 ± 11.96 t, a 14.39 t or 229% increase, and then plummeted to 1.77 ± 0.46 t in November, 1999, an 18.91 t or 91% decrease from 1998. In November, 2000, the legal biomass increased to 29.97 ± 8.90, a 1,593% increase from 1999, and then it increased again in November, 2001 to 54.63 ± 19.09 t, equal to an increase of 24.66 t or 82% over the biomass in November, 2000. In October, 2002 the legal biomass decreased by 8.36 t or 15% to 46.27 ± 19.78 t. Similar trends were observed in the sublegal-mature-sized urchins, with low biomass estimates in November, 1997 and 1999 (2.77 ± 0.97 t and 3.21 ± 1.49 t, respectively), and large increases to high biomass estimates in November, 2000 and 2001 (18.44 ± 2.82 t and 22.26 ± 4.32 t, respectively). The biomass estimates of sublegal-immature urchins were low in November, 1997 (0.10 ± 0.04 t; Waddell *et al.* 2003), increased to a peak of 0.29 ± 0.11 t in November, 1998, and then slowly decreased over the following years, to a low of 0.02 ± 0.02 t in October, 2002. The large fluctuations in biomass at the Plumper Islands may have been influenced by which particular transects were surveyed. Initially the survey was designed so that six transects were surveyed at the Plumper Islands. After a few years of surveying here, it was observed that two transects, Transects 19 and 24, had very low densities of green urchins, if any at all. A decision was made in November, 2000 to eliminate those transects from the survey. Previous to this, these transects were often skipped if there was not enough time to complete surveying at the Plumper Islands. However, if either or both of these transects were included in the calculation for densities (and ultimately for biomass), it could have biased the value for the estimated biomass to a lower value for the Plumper Islands. In addition, the Plumper Islands were harvested "by accident" in the 1998-1999 fishing season. This, along with the previous suggestion, may explain why the biomass estimate for legal-sized urchins is so extremely low for Plumper Island legal-sized urchins in November, 1999.

(f) FISHING EXPLOITATION

The fishing exploitation of legal-sized green urchins at Stephenson Islets ranged from a low of 0.08 ± 0.002 in October, 2002 to a high of 0.29 ± 0.03 in November, 2000. During the 1997-1998 fishing season, the exploitation was calculated as 0.28 ± 0.05 (Waddell *et al.* 2003). Analyzing why the exploitation varies so much between years is difficult because there are so many variables involved influencing this calculation. Exploitation is calculated as the proportion of the biomass of legal-sized green urchins harvested by the fishery from the Stephenson Islets to the estimated total biomass of legal-sized urchins at the Stephenson Islets just prior to the opening of the fishery. The amount fished from the Stephenson Islets any particular year is influenced not only by the numbers of green urchins available for harvesting (i.e. density), but also by the dynamics of the fishery, such as the Japanese market, the price per pound, directions to the fishers by the processors, fishery management regulations and changes, other fisheries competing for fishers time, weather, and various other industry-related factors. The total biomass estimates are influenced by the density estimates, which may vary depending on the transects surveyed (not always the same), and by the estimated mean individual weights of the legal-sized green urchins, which also seem to vary considerably between years.

(g) SAMPLING PROBLEMS

Sampling problems can potentially cause differences between survey results. For instance, it was noted that occasionally the divers started surveying deeper than 10.0 m below CD. Since the area estimate for Stephenson Islets was based on the 10 m isobath, and green urchins are usually sparse at depths below this, the divers' data were truncated to 10 m (33 ft) to calculate the density so that the sampling occurred within the area estimate (however, the original data were used for the size frequency analyses). Second, the divers occasionally neglected to note empty quadrats. This was evident when the recorded depths between the one meter quadrats had a difference of more than 4 ft. "Empty quadrats" were approximately added in, thus reducing the overestimate of density and biomass. Thirdly, due to various reasons (poor weather conditions, strong tidal currents, divers running out of air or having other difficulties, etc.), the divers did not always survey the full length of some of the transects. Since the divers always started at the deep end of the transect and worked their way to the shallow end, the shallower depths were not sampled sufficiently. The density by depth analyses show that densities were generally higher in the shallower depths, especially for the Stephenson Islets and Stubbs Island. Therefore, density and biomass estimates may be underestimated or for some surveys (November, 1999 in particular). There was no method available to compensate for the lack of these data.

SUMMARY

The main conclusion from these five surveys is that there was a highly successful spawn in 1998, followed by a smaller spawn in 1999, and poor juvenile recruitment in the three following years. The evidence to support this is: a large increase in the densities and biomasses of sublegal-immature green urchins in November, 1998 and 1999, followed by consecutively decreasing densities and biomasses of sublegal-immature urchins from November, 2000 to October, 2002; a general trend of increasing densities and biomasses for sublegal-mature and legal-sized urchins at all of the locations densities, even the commercially-fished Stephenson Islets (with some fluctuations in sublegal-mature densities at Stubbs Island and the Plumper Islands); and, a decrease in the number of frequency modes in the size distribution, from 2-4 in November, 1998 down to 1 in October, 2002, with the first mode getting smaller each survey.

In all five surveys, the mean test diameters and total wet weights of legal-sized urchins were generally largest at Stubbs Island, second-largest at the Plumper Islands, and smallest at the Stephenson Islets. Since the Stephenson Islets has always been open to commercial green urchin fishing since the fishery started, and has been consistently fished since before the surveys began in 1995, it is likely that the majority of the larger urchins have been removed, thus lowering the mean overall size. This is also likely why the mean test diameters for legal-sized urchins at the Stephenson Islets did not change very much over the five surveys. However, the mean total wet weights for legal-sized urchins decreased by 20.1% from November, 1998 to October, 2002. The mean total wet weight for urchins from the Plumper Islands also decreased by 11% over the same time period. The increase in legal and sublegal-mature-sized densities may mean less food was available to individual urchins, resulting in lower mean weights. However, despite the fact that the density of legal-sized and sublegal-mature-sized urchins also generally increased over the years at Stubbs Island, the mean total wet weight of legal-sized urchins from this location increased by 8% from November, 1998 to October, 2002.

When comparing between sites, Stephenson Islets had the highest density of legal-sized urchins in November, 1998, but Stubbs Island had the highest density of legal-sized urchins for every survey following. The density of sublegal-mature-sized urchins was also highest in the Stephenson Islets in November, 1998 and then highest at Stubbs Island for every following survey, except for October, 2002, when it was highest for the Stephenson Islets again. The highest density of sublegal-immature urchins occurred at the Plumper Islands in November, 1998, at Stubbs Island in November, 1999 and 2000, and in the Stephenson Islets in November, 2001 and October, 2002.

Although the green sea urchins in this study area were generally observed in greater density in shallower waters, with continuously decreasing densities with each depth increment, there were subtle differences between the sites and size classes. Legal-sized green urchins were usually found with the highest mean densities in the shallowest waters at Stephenson Islets, consistently between 0.3 and 1.5 m below CD at Stubbs Island, and at deeper depths at the Plumper Islands. Sublegal-sized urchins were observed in the highest mean densities at the Stephenson Islets between 1.2 m above CD and 4.8 m below CD, and 3 of the 5 surveys had the highest mean densities between zero CD and above. Similar results were observed at the Plumper Islands, but the highest mean densities of sublegal-sized urchins were observed between 3.3 and

4.8 m in 3 out of the 5 surveys. At Stubbs Island, sublegal-sized green urchins were in highest mean densities between 1.2 m above CD and 3.0 m below CD. The highest mean total densities were observed between 1.2 m above CD and 3.0 m below CD at the Stephenson Islets, consistently between 0.3 and 1.5 m below CD at Stubbs Island for every survey, and between 0.9 m above CD to 10.7 m below CD at the Plumper Islands, with 3 of the 5 surveys observed between 3.3 and 4.8 m below CD.

There may be a connection between high mean gonad weight and good juvenile recruitment. The gonad weights at all sites were highest in November, 1997 (Waddell *et al.* 2003), and second-highest in November, 1998. The densities and biomasses of sublegal-immature urchins increased significantly at all sites from November, 1997 to November, 1998, and increased again in November, 1999 (i.e., in the years following when the high gonad weights were observed). The mean gonad weights were all significantly lower at Stubbs Island and the Plumper Islands for all remaining surveys (except Stubbs in 2001), and the densities and biomasses of sublegal-immature-sized green sea urchins all decreased in the years following (except at Stubbs Island in 2000).

The mean roe recovery rate rates (the percentage of total gonad weights (all grades) divided by the total drained weight of all urchins collected) for legal-sized urchins from all surveys and locations ranged from 16.0 to 23.0%.

The fishing exploitation of legal-sized green urchins at Stephenson Islets ranged from a low of 0.08 ± 0.002 in October, 2002 to a high of 0.29 ± 0.03 in November, 2000. These results may be influenced by the dynamics of the green sea urchin fishery and market conditions.

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Table 1. Survey dates, vessels involved, and number of transects surveyed at each of the sites, for each of the five green urchin surveys. (WCGUA = owned by a commercial fisher of the WCGUA, DFO = owned by the DFO).

Survey Dates	Vessels Involved	Number of Transects Surveyed		
		Stephenson Islets	**Stubbs Island**	**Plumper Islands**
November 6-8, 1998	PACMAN I (WCGUA) CCC (WCGUA)	10	4	5
November 2-4, 1999	Clo-oose (WCGUA) Jibore (WCGUA)	9	4	6
November 2, 4-5, 2000	Clo-oose (WCGUA) CCC (WCGUA)	8½	3	4
November 4-6, 2001	CCC (WCGUA) Reef Runner (WCGUA)	10	4	4
October 25-27, 2002	Rufus (WCGUA) C68 (DFO)	10	3	4

Table 2. Numbers (N) and percentages (P) of green sea urchins of legal size, sublegal-mature size, sublegal-immature size, unknown size (i.e., counted only), and all sizes (total) for all sites, measured during the surveys. Note that measuring was complete (all urchins were measured in all quadrats) in the November, 1998 and 1999 surveys while measuring was incomplete (urchins were measured in most quadrats but only counted in the remainder) in the November, 2000, 2001 and October, 2002 surveys. The numbers in the brackets in the lighter font indicate the actual measured values while the darker font indicates the best estimates (the "unknowns" were proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and a zero value was assigned to the unknowns). (M=measured quadrats; T=measured plus counted quadrats; Legal ≥ 55 mm test diameter (TD); Sublegal-mature = 25 mm ≥ TD < 55 mm TD; Sublegal-immature = < 25 mm; Total Number = total number of green sea urchins measured).

Site	Survey Date	No. of Quads	N or P	Number of Legal	Number of Sublegal-mature	Number of Sublegal-immature	Number of Unknown	Total Number
All Sites Combined	Nov.	479 T	N	675	683	227	0	1,585
	1998		P	42.6%	43.1%	14.3%	0.0%	
	Nov.	561 T	N	936	1,497	296	2	2,731
	1999		P	34.3%	54.8%	10.8%	0.0%	
	Nov.	519 M	N	803 (798)	1,783 (1,763)	183 (179)	0 (29)	2.769
	2000	529 T	P	29.0% (28.8%)	64.4% (63.7%)	6.6% (6.5%)	0% (1.1%)	
	Nov.	565 M	N	1,510 (1,338)	2,412 (2,137)	155 (137)	0 (465)	4,077
	2001	630 T	P	38.7% (32.8%)	57.8% (52.6%)	3.5% (3.3%)	0%(11.3%)	
	Oct.	416 M	N	1,691 (1,136)	2,602 (1,529)	107 (64)	0 (1,671)	4,400
	2002	623 T	P	38.4% (25.8%)	59.1% (34.8%)	2.4% (1.5%)	0%(38.0%)	
Stephenson Islets	Nov.	287 T	N	501	523	135	0	1,159
	1998		P	43.2%	45.1%	11.7%	0.0%	
	Nov.	311 T	N	631	1,044	188	2	1,865
	1999		P	33.8%	56.0%	10.1%	0.0%	
	Nov.	331 M	N	395 (390)	1,133 (1,113)	111 (107)	0 (29)	1,639
	2000	341 T	P	24.1% (23.8%)	69.1% (67.9%)	6.8% (6.5%)	0% (1.8%)	
	Nov.	397 M	N	783 (736)	1,682 (1,581)	121 (114)	0 (155)	2,586
	2001	435 T	P	30.3% (28.5%)	65.0% (61.1%)	4.7% (4.4%)	0% (6.0%)	
	Oct.	257 M	N	1,122 (579)	2,240 (1,175)	95 (52)	0 (1,651)	3,457
	2002	451 T	P	32.5% (16.8%)	64.8% (34.0%)	2.8% (1.5%)	0%(47.8%)	
Stubbs Island	Nov.	69 T	N	60	61	25	0	146
	1998		P	41.1%	41.8%	17.1%	0.0%	
	Nov.	88 T	N	291	308	60	0	659
	1999		P	44.2%	46.7%	9.1%	0.0%	
	Nov.	64 T	N	197	281	41	0	519
	2000		P	38.0%	54.1%	7.9%	0.0%	
	Nov.	78 M	N	450 (396)	351 (309)	11 (10)	0 (97)	812
	2001	86 T	P	56.3% (48.9%)	42.2% (38.1%)	1.5% (1.2%)	0%(11.8%)	
	Oct.	66 T	N	321	210	7	0	538
	2002		P	59.7%	39.0%	1.3%	0.0%	

Table 2. (continued)

Site	Survey Date	No. of Quads	N or P	Number of Legal	Number of Sublegal-mature	Number of Sublegal-immature	Number of Unknown	Total Number
Plumper Islands	Nov.	123 T	N	**114**	**99**	**67**	**0**	**280**
	1998		P	**40.7%**	**35.4%**	**23.9%**	**0.0%**	
	Nov.	162 T	N	**14**	**145**	**48**	**0**	**207**
	1999		P	**6.8%**	**70.1%**	**23.2%**	**0.0%**	
	Nov.	124 T	N	**211**	**369**	**31**	**0**	**611**
	2000		P	**34.5%**	**60.4%**	**5.1%**	**0.0%**	
	Nov.	90 M	N	**300** (206)	**360** (247)	**19** (13)	**0** (213)	**679**
	2001	109 T	P	**44.2%**(30.3%)	**53.0%)** (36.4%)	**2.8%** (1.9%)	**0%**(31.4%)	
	Oct.	93 M	N	**248** (236)	**152** (144)	**5** (5)	**0** (20)	**405**
	2002	106 T	P	**61.2%**(58.3%)	**37.5%** (35.6%)	**1.2%** (1.2%)	**0%** (4.9%)	

Table 3. Green sea urchin test diameter frequency distribution analysis for the November, 1998, 1999, 2000, 2001 and October, 2002 surveys. Results were obtained using the analysis software "Mix 3aa" (Macdonald 1994). (Sigma = standard deviation, X^2 = chi-square goodness of fit value, DF = degrees of freedom, P-value = the p-value of the chi-square test).

Site	Survey	Frequency Mode	Mode Mean (mm)	Sigma (mm)	Proportion Of Population	X^2	DF	P-value
All Sites Combined	Nov. 1998	1	8	2.0	0.05	172.9	38	<0.0001
		2	28	12.4	0.27			
		3	55	8.8	0.69			
	Nov. 1999	1	33	10.3	0.58	229.0	37	<0.0001
		2	59	8.2	0.42			
	Nov. 2000	1	31	11.2	0.25	191.2	37	<0.0001
		2	51	10.0	0.75			
	Nov. 2001	1	44	13.3	0.60	206.0	35	<0.0001
		2	55	7.7	0.40			
	Oct. 2002	1	51	12.1	1.00	200.0	38	<0.0001
Stephenson Islets	Nov. 1998	1	8	1.9	0.05	157.9	34	<0.0001
		2	24	10.8	0.14			
		3	36	3.3	0.04			
		4	54	8.5	0.77			
	Nov. 1999	1	35	11.0	0.62	166.8	35	<0.0001
		2	59	6.8	0.38			
	Nov. 2000	1	10	2.9	0.03	138.2	32	<0.0001
		2	46	11.5	0.97			
	Nov. 2001	1	43	13.2	0.56	136.1	33	<0.0001
		2	52	7.4	0.44			
	Oct. 2002	1	48	11.3	1.00	183.4	34	<0.0001

Table 3. (continued)

Site	Survey	Frequency Mode	Mode Mean (mm)	Sigma (mm)	Proportion Of Population	X^2	DF	P-value
Stubbs Island	Nov. 1998	1	25	7.6	0.40	49.1	33	0.0354
		2	57	9.7	0.60			
	Nov. 1999	1	33	10.4	0.50	73.1	36	0.0003
		2	62	9.2	0.50			
	Nov. 2000	1	21	5.5	0.10	70.6	36	0.0005
		2	52	10.4	0.90			
	Nov. 2001	1	30	6.1	0.16	76.8	34	<0.0001
		2	57	8.9	0.84			
	Oct. 2002	1	56	12.9	1.00	81.2	36	<0.0001
Plumper Islands	Nov. 1998	1	6	1.9	0.09	52.3	30	0.0070
		2	28	11.4	0.39			
		3	60	8.4	0.52			
	Nov. 1999	1	27	7.0	0.82	78.0	25	<0.0001
		2	45	3.3	0.11			
		3	60	2.6	0.05			
		4	73	3.1	0.02			
	Nov. 2000	1	32	7.2	0.39	73.6	32	<0.0001
		2	55	8.3	0.61			
	Nov. 2001	1	30	5.9	0.23	53.1	28	0.0028
		2	56	9.4	0.77			
	Oct. 2002	1	55	11.2	1.00	115.1	34	<0.0001

Table 4. Means and standard errors (SE) of test diameters (TD) (using November, 1998 field survey data) and weights (using TD-total wet weight relationships from November, 1998 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	707	61.2	0.2	92.3	1.0
	Sublegal-Mature	717	42.7	0.3	39.1	0.6
	Sublegal-Immature	231	13.2	0.4	2.6	0.2
Stephenson Islets	Legal	516	60.6	0.3	89.9	1.1
	Sublegal-Mature	547	44.1	0.3	41.8	0.7
	Sublegal-Immature	137	12.8	0.5	2.4	0.2
Stubbs Island	Legal	63	62.2	0.9	96.7	3.6
	Sublegal-Mature	64	37.8	1.2	29.9	2.2
	Sublegal-Immature	25	18.5	0.8	4.7	0.5
Plumper Islands	Legal	128	63.1	0.6	99.8	2.3
	Sublegal-Mature	106	38.3	0.9	30.6	1.7
	Sublegal-Immature	69	12.1	0.8	2.4	0.3

Table 5. Sample mean densities (urchins/m^2) by transect and overall standard errors for green sea urchins of legal size, sublegal size, unknown size, and all sizes (total) in the November, 1998 survey. (Legal $\geq$ 55 mm TD, Sublegal-mature 25 mm $\geq$ TD $<$ 55 mm, Sublegal-immature $<$ 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 20 to 24.

Transect Number	**Number of Quadrats**	**Legal Density**	**Sublegal – Mature Density**	**Sublegal – Immature Density**	**Unknown Density**	**Total Density**
3	57	1.58	0.61	0.21	0.00	2.40
5A	20	1.10	5.90	0.30	0.00	7.30
6	23	1.74	2.22	0.43	0.00	4.39
7	21	1.19	1.67	0.10	0.00	2.95
8	15	0.20	0.40	0.00	0.00	0.60
9	24	0.71	2.92	0.08	0.00	3.71
10	22	0.68	0.27	0.00	0.00	0.95
11	48	4.63	1.48	0.13	0.00	6.23
13	31	2.06	3.61	2.68	0.00	8.35
14	26	0.12	0.73	0.54	0.00	1.38
Stephenson Islets Totals	287	1.75 ± 0.56	1.82 ± 0.49	0.47 ± 0.27	0.00	4.04 ± 0.86
15	17	0.47	1.06	0.06	0.00	1.59
16	9	0.33	0.00	0.00	0.00	0.33
17	28	1.36	1.50	0.86	0.00	3.71
18	15	0.73	0.07	0.00	0.00	0.80
Stubbs Island Totals	69	0.87 ± 0.27	0.88 ± 0.38	0.36 ± 0.27	0.00	2.12 ± 0.87
20	35	0.37	1.00	0.11	0.00	1.49
21	27	0.89	0.67	0.96	0.00	2.52
22	26	2.88	1.19	0.31	0.00	4.38
23	14	0.14	0.57	0.71	0.00	1.43
24	21	0.00	0.33	0.90	0.00	1.24
Plumper Islands Totals	123	0.93 ± 0.54	0.82 ± 0.15	0.54 ± 0.19	0.00	2.28 ± 0.61
OVERALL TOTAL	479	1.41 ± 0.38	1.43 ± 0.30	0.47 ± 0.17	0.00	3.31 ± 0.58

Table 6a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below Chart Datum from all survey sites combined in the November, 1998 survey. (Legal ≥ 55 mm TD, Sublegal < 55 mm TD. No unmeasured urchins in this survey).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-8 to -5	-2.4 to -1.5	15	0.13	0.07	0.20 ± 0.11
-4 to 0	-1.2 to 0.0	36	1.22	1.14	2.36 ± 0.83
1 to 5	0.3 to 1.5	62	2.71	2.68	5.39 ± 0.74
6 to 10	1.8 to 3.0	78	1.53	2.19	3.72 ± 0.61
11 to 15	3.3 to 4.8	70	1.23	2.59	3.81± 0.60
16 to 20	4.9 to 6.1	79	1.67	1.81	3.48 ± 0.56
21 to 25	6.4 to 7.6	72	0.58	1.65	2.24 ± 0.35
26 to 30	7.9 to 9.1	72	0.40	1.22	1.63 ± 0.29
31 to 35	9.4 to 10.7	44	1.80	0.73	2.55 ± 1.00
36 to 40	11.0 to 12.2	13	0.46	0.46	0.92 ± 0.37
41 to 45	12.5 to 13.7	6	0.00	0.00	0.00
46 to 47	14.0 to 14.3	1	0.00	0.00	0.00

Table 6b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below Chart Datum in the Stephenson Islets in the November, 1998 survey. (Legal ≥ 55 mm TD, Sublegal < 55 mm TD. No unmeasured urchins in this survey).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-8 to -5	-2.4 to -1.5	13	0.15	0.08	0.23 ± 0.12
-4 to 0	-1.2 to 0.0	22	1.68	1.23	2.91 ± 1.31
1 to 5	0.3 to 1.5	42	3.19	2.69	5.88 ± 1.00
6 to 10	1.8 to 3.0	58	1.90	2.36	4.26 ± 0.79
11 to 15	3.3 to 4.8	37	1.81	3.41	5.22 ± 0.90
16 to 20	4.9 to 6.1	45	2.40	2.31	4.71 ± 0.89
21 to 25	6.4 to 7.6	46	0.50	2.17	2.67 ± 0.48
26 to 30	7.9 to 9.1	44	0.48	1.39	1.86 ± 0.41
31 to 35	9.4 to 10.7	16	0.88	0.75	1.63 ± 0.60
36 to 40	11.0 to 12.2	6	0.00	0.50	0.50 ± 0.22
41 to 45	12.5 to 13.7	5	0.00	0.00	0.00
46 to 47	14.0 to 14.3	1	0.00	0.00	0.00

Table 6c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below Chart Datum at Stubbs Island in the November, 1998 survey. (Legal ≥ 55 mm TD, Sublegal < 55 mm TD. No unmeasured urchins in this survey).

Depth Range (ft)	**Depth Range (m)**	**Number of Quadrats**	**Legal Density**	**Sublegal Density**	**Total Density**
-1 to 0	-0.3 to 0.0	1	2.00	2.00	4.00 ± 0.00
1 to 5	0.3 to 1.5	6	2.33	2.83	5.17 ± 2.12
6 to 10	1.8 to 3.0	8	1.00	2.75	3.75 ± 1.24
11 to 15	3.3 to 4.8	16	0.94	1.94	2.88 ± 1.23
16 to 20	4.9 to 6.1	13	1.54	1.00	2.54 ± 0.72
21 to 25	6.4 to 7.6	8	0.13	0.13	0.25 ± 0.25
26 to 30	7.9 to 9.1	7	0.00	0.14	0.14 ± 0.14
31 to 35	9.4 to 10.7	7	0.29	0.14	0.43 ± 0.20
36 to 40	11.0 to 12.2	5	0.20	0.20	0.40 ± 0.40
41 to 42	12.5 to 12.8	1	0.00	0.00	0.00

Table 6d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below Chart Datum in the Plumper Islands in the November, 1998 survey. (Legal ≥ 55 mm TD, Sublegal < 55 mm TD. No unmeasured urchins in this survey).

Depth Range (ft)	**Depth Range (m)**	**Number of Quadrats**	**Legal Density**	**Sublegal Density**	**Total Density**
-7 to -5	-2.1 to -1.5	2	0.00	0.00	0.00
-4 to 0	-1.2 to 0.0	12	0.33	0.92	1.25 ± 0.58
1 to 5	0.3 to 1.5	14	1.29	2.36	3.64 ± 1.06
6 to 10	1.8 to 3.0	13	0.46	1.69	2.15 ± 0.71
11 to 15	3.3 to 4.8	13	0.15	1.31	1.46 ± 0.56
16 to 20	4.9 to 6.1	19	0.16	0.47	0.63 ± 0.24
21 to 25	6.4 to 7.6	21	0.90	1.57	2.48 ± 0.71
26 to 30	7.9 to 9.1	22	0.36	1.18	1.55 ± 0.41
31 to 35	9.4 to 10.7	21	3.00	1.05	4.10 ± 2.01
36 to 37	11.0 to 11.3	4	1.25	0.50	1.75 ± 1.03

Table 7a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 1998 survey (all areas combined). (Legal ≥ 55 mm TD, Sublegal < 55 mm TD, Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins in this survey).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	181	0.85	2.03	2.88	2.71 ± 0.28
120	Bedrock (smooth)/bedrock (crevices)	1	0.00	0.00	0.00	
130	Bedrock (smooth)/boulders	1	0.00	1.00	1.00	
140	Bedrock (smooth)/cobble	11	0.00	0.91	0.91	
148	Bedrock (smooth)/cobble/shell	4	1.00	2.25	3.25	
158	Bedrock (smooth)/gravel/shell	1	0.00	10.00	10.00	
180	Bedrock (smooth)/shell	9	0.11	1.11	1.22	
184	Bedrock (smooth)/shell/cobble	1	0.00	0.00	0.00	
200	Bedrock (crevices)	163	2.28	2.09	4.37	4.22 ± 0.43
230	Bedrock (crevices)/boulders	4	1.75	1.25	3.00	
234	Bedrock (crevices)/boulders/ cobble	1	0.00	0.00	0.00	
240	Bedrock (crevices)/cobble	2	2.00	2.00	4.00	
250	Bedrock (crevices)/gravel	2	0.50	3.00	3.50	
280	Bedrock (crevices)/shell	9	1.11	1.56	2.67	
300	Boulders	41	2.24	1.90	4.15	4.05 ± 0.77
310	Boulders/bedrock (smooth)	3	0.33	6.00	6.33	
320	Boulders/bedrock (crevices)	1	1.00	2.00	3.00	
340	Boulders/cobble	8	1.13	1.88	3.00	
348	Boulders/cobble/shell	2	2.00	1.50	3.50	
350	Boulders/gravel	4	3.50	1.25	4.75	
380	Boulders/shell	1	0.00	1.00	1.00	
400	Cobble	7	0.14	0.86	1.00	0.67 ± 0.29
410	Cobble/bedrock (smooth)	1	0.00	1.00	1.00	
450	Cobble/gravel	3	0.00	0.33	0.33	
470	Cobble/sand	1	0.00	0.00	0.00	
480	Cobble/shell	3	0.33	0.00	0.33	
500	Gravel	4	0.00	0.00	0.00	0.38 ± 0.38
540	Gravel/cobble	4	0.00	0.75	0.75	
750	Sand/gravel	6	0.00	0.00	0.00	0.00

Table 7b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 1998 survey (Stephenson Islets only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins in this survey).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	76	1.13	3.18	4.32	3.83 ± 0.54
120	Bedrock (smooth)/bedrock (crevices)	1	0.00	0.00	0.00	
140	Bedrock (smooth)/cobble	9	0.00	0.11	0.11	
200	Bedrock (crevices)	147	2.49	2.24	4.73	4.72 ± 0.50
230	Bedrock (crevices)/boulders	2	2.00	1.00	3.00	
240	Bedrock (crevices)/cobble	2	2.00	2.00	4.00	
280	Bedrock (crevices)/shell	1	5.00	4.00	9.00	
300	Boulders	23	0.96	1.91	2.87	3.33 ± 0.56
310	Boulders/bedrock (smooth)	2	0.00	6.00	6.00	
320	Boulders/bedrock (crevices)	1	1.00	2.00	3.00	
340	Boulders/cobble	3	3.00	1.67	4.67	
348	Boulders/cobble/shell	1	3.00	2.00	5.00	
400	Cobble	7	0.14	0.86	1.00	0.82 ± 0.38
410	Cobble/bedrock (smooth)	1	0.00	1.00	1.00	
450	Cobble/gravel	2	0.00	0.50	0.50	
470	Cobble/sand	1	0.00	0.00	0.00	
500	Gravel	4	0.00	0.00	0.00	0.38 ± 0.38
540	Gravel/cobble	4	0.00	0.75	0.75	

Table 7c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 1998 survey (Stubbs Island only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins in this survey).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	61	0.85	1.18	2.03	2.17 ± 0.46
140	Bedrock (smooth)/cobble	1	0.00	5.00	5.00	
148	Bedrock (smooth)/cobble/shell	1	3.00	5.00	8.00	
200	Bedrock (crevices)	4	0.25	0.25	0.50	1.40 ± 0.93
280	Bedrock (crevices)/shell	1	3.00	2.00	5.00	
348	Boulders/cobble/shell	1	1.00	1.00	2.00	2.00 ± 0.00

Table 7d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 1998 survey (Plumper Islands only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins in this survey).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	44	0.34	1.23	1.57	1.67 ± 0.30
130	Bedrock (smooth)/boulders	1	0.00	1.00	1.00	
140	Bedrock (smooth)/cobble	1	0.00	4.00	4.00	
148	Bedrock (smooth)/cobble/shell	3	0.33	1.33	1.67	
158	Bedrock (smooth)/gravel/shell	1	0.00	10.00	10.00	
180	Bedrock (smooth)/shell	9	0.11	1.11	1.22	
184	Bedrock (smooth)/shell/cobble	1	0.00	0.00	0.00	
200	Bedrock (crevices)	12	0.42	0.83	1.25	1.58 ± 0.39
230	Bedrock (crevices)/boulders	2	1.50	1.50	3.00	
234	Bedrock (crevices)/boulders/cobble	1	0.00	0.00	0.00	
250	Bedrock (crevices)/gravel	2	0.50	3.00	3.50	
280	Bedrock (crevices)/shell	7	0.29	1.14	1.43	
300	Boulders	18	3.89	1.89	5.78	4.86 ± 1.49
310	Boulders/bedrock (smooth)	1	1.00	6.00	7.00	
340	Boulders/cobble	5	0.00	2.00	2.00	
350	Boulders/gravel	4	3.50	1.25	4.75	
380	Boulders/shell	1	0.00	1.00	1.00	
450	Cobble/gravel	1	0.00	0.00	0.00	0.25 ± 0.25
480	Cobble/shell	3	0.33	0.00	0.33	
750	Sand/gravel	6	0.00	0.00	0.00	0.00

Table 8. Summary results of measurements taken during green urchin dissections from the November, 1998 survey. (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, SE = Standard error, Gutted Weight = stomach and contents removed; Gonad Colour: 0=unknown or not present, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or not present, 1=firm, 2=semi-firm, 3=flimsy). Sample Size is for all calculations.

Summary Information			**Site**								
			Stephenson Islets			**Stubbs Island**			**Plumper Islands**		
			Legal	**Sublegal - mature**	**Sublegal – immature**	**Legal**	**Sublegal – mature**	**Sublegal – immature**	**Legal**	**Sublegal – mature**	**Sublegal – immature**
Sample Size			36	44	1	9	8	0	19	11	0
Mean Test Height (mm) ± SE			30.7 (± 0.6)	21.6 (± 0.7)	11.0	32.6 (± 1.5)	26.0 (± 1.2)	0	31.7 (± 0.8)	22.2 (± 1.3)	0
Mean Test Diameter (mm) ± SE			62.1 (± 0.9)	44.8 (± 1.1)	23.0	62.0 (± 1.7)	50.0 (± 1.9)	0	62.8 (± 1.4)	44.9 (± 2.3)	0
Mean Total Wet Weight (g) ± SE			94.39 (± 4.44)	43.24 (± 2.74)	15.50	109.24 (± 7.24)	63.34 (± 5.11)	0	94.78 (± 6.04)	42.53 (± 5.04)	0
Mean Drained Weight (g) ± SE			73.72 (± 3.60)	35.94 (± 2.13)	13.50	85.17 (± 6.47)	52.06 (± 4.39)	0	73.82 (± 4.34)	35.72 (± 3.98)	0
Mean Gutted Weight (g) ± SE			54.77 (± 2.82)	27.08 (± 1.68)	9.60	69.21 (± 5.41)	37.98 (± 3.03)	0	54.41 (± 3.06)	26.03 (± 3.28)	0
Mean Stomach and Content Weight (g) ± SE			18.95 (± 1.26)	8.86 (± 0.59)	3.90	19.99 (± 1.52)	14.09 (± 1.61)	0	19.41 (± 1.86)	9.69 (± 1.05)	0
Sex	% Male		25	34	0	22	50	0	53	27	0
	% Female		72	45	0	78	50	0	47	45	0
	% Unknown		3	20	100	0	0	0	0	27	0
Gonad	Mean Weight (g) ± SE		13.78 (± 1.19)	6.21 (± 0.61)	0.60	17.22 (± 3.10)	8.55 (± 1.28)	0	13.74 (± 1.30)	5.93 (± 1.35)	0
	Colour Proportion	0	0	0	0	0	0	0	0	0	0
		1	0.61	0.75	1	0.67	0.88	0	0.58	1.00	0
		2	0.33	0.20	0	0.22	0.13	0	0.42	0	0
		3	0.06	0.05	0	0.11	0	0	0	0	0
	Texture Proportion	0	0	0	0	0	0	0	0	0	0
		1	0.94	0.91	1.00	1.00	0.88	0	0.95	0.64	0
		2	0.06	0.09	0	0	0.13	0	0	0.36	0
		3	0	0	0	0	0	0	0.05	0	0

Table 9. Comparisons of percentage of highest roe quality (roe with best colour and texture) and mean roe recovery rates (total gonad weight divided by total drained weight) between the November 1998, 1999, 2000, and 2001, and October, 2002 surveys at Stephenson Islets, Stubbs Island and Plumper Islands. (Sample size = total number of urchins with roe).

Location	**Sample Size**		**Highest Quality Roe**		**Mean Roe Recovery Rates**	
	Legal	**Sublegal**	**Legal**	**Sublegal**	**Legal**	**Sublegal**
Stephenson Islets						
November 1998	36	45	55.6%	71.1%	18.7%	17.2%
November 1999	30	43	53.3%	55.8%	19.7%	12.7%
November 2000	31	39	58.1%	66.7%	17.7%	13.0%
November 2001	46	41	43.5%	58.5%	16.0%	14.9%
October 2002	40	46	77.5%	60.9%	17.9%	12.4%
Stubbs Island						
November 1998	9	8	66.7%	87.5%	20.2%	16.4%
November 1999	17	18	58.8%	22.2%	22.2%	15.8%
November 2000	12	13	91.7%	76.9%	23.0%	22.2%
November 2001	20	16	40.0%	50.0%	21.1%	12.0%
October 2002	14	12	71.4%	41.7%	17.2%	17.4%
Plumper Islands						
November 1998	19	11	57.9%	63.6%	18.6%	16.6%
November 1999	11	22	72.7%	50.0%	17.2%	12.5%
November 2000	15	13	80.0%	84.6%	20.6%	14.7%
November 2001	18	24	50.0%	75.0%	20.0%	15.8%
October 2002	15	9	86.7%	33.3%	17.4%	15.7%

Table 10. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in November, 1998 (no unknowns in this survey). (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Size Category	**Stephenson Islets**	**Stubbs Island**	**Plumper Islands**
Number of Legal-sized	846,987 ± 270,812	17,043 ± 5,287	207,239 ± 119,713
Number of Sublegal-mature	884,180 ± 238,771	17,328 ± 7,479	179,971 ± 33,444
Number of Sublegal-immature	228,230 ± 132,111	7,101 ± 5,276	121,798 ± 43,366
Number of all sizes	1,959,397 ± 416,308	41,472 ± 17,139	509,008 ± 135,268
Biomass of Legal-size (t)	76.14 ± 24.35	1.65 ± 0.51	20.68 ± 11.96
Biomass of Sublegal-mature (t)	36.96 ± 9.99	0.52 ± 0.23	5.52 ± 1.04
Biomass of Sublegal-immature (t)	0.55 ± 0.32	0.03 ± 0.03	0.29 ± 0.11
Total Biomass (t)	113.64 ± 26.33	2.20 ± 0.56	26.48 ± 12.00

Table 11. Means and standard errors (SE) of test diameters (TD) (using November, 1999 field survey data) and weights (using TD-total wet weight relationships from November, 1999 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	1022	62.7	0.2	84.6	0.8
	Sublegal-Mature	1727	38.4	0.2	24.6	0.3
	Sublegal-Immature	316	18.1	0.3	3.4	0.1
Stephenson Islets	Legal	688	61.6	0.2	80.5	0.8
	Sublegal-Mature	1203	39.0	0.2	25.5	0.4
	Sublegal-Immature	199	17.8	0.4	3.3	0.1
Stubbs Island	Legal	317	64.8	0.4	93.3	1.6
	Sublegal-Mature	366	38.8	0.4	25.1	0.7
	Sublegal-Immature	64	18.4	0.6	3.5	0.2
Plumper Islands	Legal	17	64.4	1.7	91.5	6.9
	Sublegal-Mature	158	32.8	0.6	16.1	0.8
	Sublegal-Immature	53	18.8	0.6	3.6	0.3

Table 12. Sample mean densities (urchins/m^2) by transect and overall standard errors for green sea urchins of legal size, sublegal size, unknown size, and all sizes (total) in the November, 1999 survey. (Legal = ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 19 to 24.

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	20	5.90	2.25	0.85	0.00	9.00
5A	28	0.36	1.07	0.14	0.00	1.57
6	46	0.91	3.24	0.37	0.00	4.52
7	51	3.06	3.27	0.67	0.04	7.04
8	16	1.00	1.88	0.75	0.00	3.63
9	47	3.45	2.91	0.77	0.00	7.13
10	16	0.69	2.00	0.88	0.00	3.56
13	47	1.74	6.21	0.40	0.00	8.36
14	40	0.85	4.05	0.88	0.00	5.78
Stephenson Islets Totals	311	2.03 ± 0.50	3.36 ± 0.54	0.60 ± 0.08	0.006 ± 0.006	6.00 ± 0.72
15	16	6.19	4.00	0.63	0.00	10.81
16	27	2.67	3.44	0.48	0.00	6.59
17	31	3.71	4.87	1.19	0.00	9.77
18	14	0.36	0.00	0.00	0.00	0.36
Stubbs Island Totals	88	3.31 ± 0.86	3.50 ± 0.86	0.68 ± 0.25	0.00	7.49 ± 1.78
19	15	0.00	0.00	0.00	0.00	0.00
20	61	0.07	0.87	0.08	0.00	1.02
21	17	0.12	0.53	0.24	0.00	0.88
22	29	0.17	1.93	1.14	0.00	3.24
23	20	0.10	0.75	0.00	0.00	0.85
24	20	0.05	0.60	0.30	0.00	0.95
Plumper Islands Totals	162	0.09 ± 0.02	0.90 ± 0.41	0.30 ± 0.19	0.00	1.28 ± 0.43
OVERALL TOTAL	561	1.67 ± 0.40	2.67 ± 0.45	0.53 ± 0.09	0.004 ± 0.004	4.87 ± 0.79

Table 13a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD from all survey sites combined in the November, 1999 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-9 to -5	-2.7 to -1.5	25	0.16	1.00	1.16 ± 0.48
-4 to 0	-1.2 to 0.0	61	2.18	5.57	7.75 ± 1.04
1 to 5	0.3 to 1.5	69	2.52	4.59	7.12 ± 1.07
6 to 10	1.8 to 3.0	56	2.98	4.93	7.91 ± 0.88
11 to 15	3.3 to 4.8	103	2.31	4.36	6.67 ± 0.58
16 to 20	4.9 to 6.1	84	1.92	2.88	4.80 ± 0.60
21 to 25	6.4 to 7.6	54	1.28	2.19	3.46 ± 0.51
26 to 30	7.9 to 9.1	98	0.63	2.30	2.93 ± 0.38
31 to 35	9.4 to 10.7	63	0.21	0.60	0.81 ± 0.19
36 to 40	11.0 to 12.2	17	0.18	0.88	1.06 ± 0.50

Table 13b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by depth range (feet and meters) below CD in the Stephenson Islets in the November, 1999 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-7 to -5	-2.1 to -1.5	17	0.00	1.18	1.18 ± 0.49
-4 to 0	-1.2 to 0.0	27	2.37	6.19	8.56 ± 1.76
1 to 5	0.3 to 1.5	36	2.11	5.83	7.94 ± 1.38
6 to 10	1.8 to 3.0	29	3.17	6.10	9.28 ± 1.10
11 to 15	3.3 to 4.8	66	3.06	4.64	7.70 ± 0.69
16 to 20	4.9 to 6.1	52	2.56	3.92	6.48 ± 0.80
21 to 25	6.4 to 7.6	31	1.77	2.90	4.68 ± 0.70
26 to 30	7.9 to 9.1	70	0.84	3.00	3.84 ± 0.48
31 to 35	9.4 to 10.7	25	0.36	0.80	1.16 ± 0.39
36 to 38	11.0 to 11.6	5	0.00	0.00	0.00

Table 13c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD at Stubbs Island in the November, 1999 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. No unmeasured urchins).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Total Density
-9 to -5	-2.7 to -1.5	8	0.50	0.63	1.13 ± 1.13
-4 to 0	-1.2 to 0.0	22	3.05	7.05	10.09 ± 1.57
1 to 5	0.3 to 1.5	14	6.86	5.79	12.64 ± 3.00
6 to 10	1.8 to 3.0	15	4.93	4.87	9.80 ± 1.66
11 to 15	3.3 to 4.8	13	2.69	6.00	8.69 ± 1.94
16 to 20	4.9 to 6.1	8	3.25	2.63	5.88 ± 1.92
21 to 25	6.4 to 7.6	6	2.17	1.50	3.67 ± 1.50
26 to 30	7.9 to 9.1	10	0.10	0.80	0.90 ± 0.59
31 to 35	9.4 to 10.7	5	0.20	0.00	0.20 ± 0.20
36 to 38	11.0 to 11.6	2	0.00	0.00	0.00

Table 13d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Plumper Islands in the November, 1999 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. No unmeasured urchins).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-4 to 0	-1.2 to 0.0	12	0.17	1.50	1.67 ± 0.70
1 to 5	0.3 to 1.5	19	0.11	1.37	1.47 ± 0.94
6 to 10	1.8 to 3.0	12	0.08	2.17	2.25 ± 1.56
11 to 15	3.3 to 4.8	24	0.04	2.71	2.75 ± 0.83
16 to 20	4.9 to 6.1	24	0.08	0.71	0.79 ± 0.30
21 to 25	6.4 to 7.6	17	0.06	1.12	1.18 ± 0.59
26 to 30	7.9 to 9.1	18	0.11	0.39	0.50 ± 0.26
31 to 35	9.4 to 10.7	33	0.09	0.55	0.64 ± 0.20
36 to 40	11.0 to 12.2	10	0.30	1.50	1.80 ± 0.77

Table 14a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 1999 survey (all areas combined). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured; Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	108	1.46	2.78	0.00	4.24	4.47 ± 0.50
120	Bedrock (smooth)/bedrock (crevices)	8	2.38	1.75	0.00	4.13	
128	Bedrock (smooth)/bedrock (crevices)/shell	2	0.00	0.00	0.00	0.00	
130	Bedrock (smooth)/boulders	4	0.25	0.00	0.00	0.25	
140	Bedrock (smooth)/cobble	1	2.00	16.00	0.00	18.00	
148	Bedrock (smooth)/cobble/shell	1	0.00	3.00	0.00	3.00	
180	Bedrock (smooth)/shell	8	3.25	6.38	0.00	9.63	
200	Bedrock (crevices)	284	1.53	3.37	0.01	4.90	5.06 ± 0.32
210	Bedrock (crevices)/bedrock (smooth)	3	5.67	3.67	0.00	9.33	
230	Bedrock (crevices)/boulders	4	0.25	6.25	0.00	6.50	
234	Bedrock (crevices)/boulders/cobble	1	7.00	2.00	0.00	9.00	
238	Bedrock (crevices)/boulders/shell	5	3.60	3.00	0.00	6.60	
240	Bedrock (crevices)/cobble	13	3.54	2.77	0.00	6.31	
243	Bedrock (crevices)/cobble/boulders	1	6.00	4.00	0.00	10.00	
280	Bedrock (crevices)/shell	13	1.38	3.54	0.00	4.92	
283	Bedrock (crevices)/shell/boulders	1	0.00	0.00	0.00	0.00	
300	Boulders	23	1.74	1.22	0.00	2.96	4.55 ± 0.98
320	Boulders/bedrock (crevices)	1	19.00	12.00	0.00	31.00	
324	Boulders/bedrock (crevices)/cobble	1	1.00	4.00	0.00	5.00	
325	Boulders/bedrock (crevices)/gravel	1	0.00	1.00	0.00	1.00	
340	Boulders/cobble	9	2.00	5.56	0.00	7.56	
342	Boulders/cobble/bedrock (crevices)	1	22.00	10.00	0.00	32.00	
345	Boulders/cobble/gravel	1	0.00	3.00	0.00	3.00	
348	Boulders/cobble/shell	4	0.75	2.25	0.00	3.00	
358	Boulders/gravel/shell	1	0.00	3.00	0.00	3.00	
380	Boulders/cobble/shell	10	0.10	0.80	0.00	0.90	
382	Boulders/shell/bedrock (crevices)	1	4.00	5.00	0.00	9.00	
400	Cobble	10	3.30	5.10	0.00	8.40	7.19 ± 1.37
420	Cobble/bedrock (crevices)	1	10.00	5.00	0.00	15.00	
423	Cobble/bedrock (crevices)/boulders	1	0.00	12.00	0.00	12.00	
430	Cobble/boulders	3	0.67	4.00	0.00	4.67	
438	Cobble/boulders/shell	1	18.00	16.00	0.00	34.00	
450	Cobble/gravel	3	0.00	2.67	0.00	2.67	
458	Cobble/gravel/shell	5	0.20	0.60	0.00	0.80	
480	Cobble/shell	5	0.20	7.60	0.00	7.80	
482	Cobble/shell/bedrock (crevices)	1	3.00	6.00	0.00	9.00	
485	Cobble/shell/gravel	1	0.00	4.00	0.00	4.00	

Table 14a. (continued)

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
583	Gravel/shell/boulders	1	0.00	3.00	0.00	3.00	3.00 ± 0.00
600	Pea gravel	2	3.00	10.50	0.00	13.50	13.50 ± 4.50
800	Shell	2	0.00	0.00	0.00	0.00	0.12 ± 0.08
820	Shell/bedrock (crevices)	1	0.00	0.00	0.00	0.00	
850	Shell/gravel	13	0.00	0.15	0.00	0.15	
854	Shell/gravel/cobble	1	0.00	0.00	0.00	0.00	

Table 14b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 1999 survey (Stephenson Islets only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured; Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	26	1.96	4.50	0.00	6.46	6.55 ± 0.97
120	Bedrock (smooth)/bedrock (crevices)	3	3.33	2.00	0.00	5.33	
130	Bedrock (smooth)/boulders	1	1.00	0.00	0.00	1.00	
140	Bedrock (smooth)/cobble	1	2.00	16.00	0.00	18.00	
148	Bedrock (smooth)/cobble/shell	1	0.00	3.00	0.00	3.00	
180	Bedrock (smooth)/shell	6	3.17	4.00	0.00	7.17	
200	Bedrock (crevices)	184	1.85	3.92	0.01	5.78	5.98 ± 0.41
210	Bedrock (crevices)/bedrock (smooth)	3	5.67	3.67	0.00	9.33	
230	Bedrock (crevices)/boulders	1	1.00	3.00	0.00	4.00	
234	Bedrock (crevices)/boulders/cobble	1	7.00	2.00	0.00	9.00	
238	Bedrock (crevices)/boulders/shell	1	0.00	3.00	0.00	3.00	
240	Bedrock (crevices)/cobble	10	4.40	2.80	0.00	7.20	
243	Bedrock (crevices)/cobble/boulders	1	6.00	4.00	0.00	10.00	
280	Bedrock (crevices)/shell	7	2.14	5.43	0.00	7.57	
300	Boulders	23	1.74	1.22	0.00	2.96	4.39 ± 0.87
324	Boulders/bedrock (crevices)/cobble	1	1.00	4.00	0.00	5.00	
340	Boulders/cobble	6	3.00	8.17	0.00	11.17	
345	Boulders/cobble/gravel	1	0.00	3.00	0.00	3.00	
348	Boulders/cobble/shell	4	0.75	2.25	0.00	3.00	
358	Boulders/gravel/shell	1	0.00	3.00	0.00	3.00	
400	Cobble	10	3.30	5.10	0.00	8.40	7.12 ± 1.15
420	Cobble/bedrock (crevices)	1	10.00	5.00	0.00	15.00	
423	Cobble/bedrock (crevices)/boulders	1	0.00	12.00	0.00	12.00	
430	Cobble/boulders	3	0.67	4.00	0.00	4.67	
450	Cobble/gravel	3	0.00	2.67	0.00	2.67	
458	Cobble/gravel/shell	1	0.00	0.00	0.00	0.00	
480	Cobble/shell	5	0.20	7.60	0.00	7.80	
482	Cobble/shell/bedrock (crevices)	1	3.00	6.00	0.00	9.00	
485	Cobble/shell/gravel	1	0.00	4.00	0.00	4.00	
583	Gravel/shell/boulders	1	0.00	3.00	0.00	3.00	3.00 ± 0.00
600	Pea gravel	2	3.00	10.50	0.00	13.50	13.50 ± 4.50

Table 14c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 1999 survey (Stubbs Island only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	33	3.15	4.52	7.67	7.41 ± 1.00
120	Bedrock (smooth)/bedrock (crevices)	5	1.80	1.60	3.40	
130	Bedrock (smooth)/boulders	1	0.00	0.00	0.00	
180	Bedrock (smooth)/shell	2	3.50	13.50	17.00	
200	Bedrock (crevices)	34	2.50	3.47	5.97	5.93 ± 0.94
238	Bedrock (crevices)/boulders/shell	4	4.50	3.00	7.50	
240	Bedrock (crevices)/cobble	1	2.00	4.00	6.00	
280	Bedrock (crevices)/shell	2	1.50	3.50	5.00	
283	Bedrock (crevices)/shell/boulders	1	0.00	0.00	0.00	
320	Boulders/bedrock (crevices)	1	19.00	12.00	31.00	24.00 ± 7.51
342	Boulders/cobble/bedrock (crevices)	1	22.00	10.00	32.00	
382	Boulders/shell/bedrock (crevices)	1	4.00	5.00	9.00	
438	Cobble/boulders/shell	1	18.00	16.00	34.00	34.00 ± 0.00
820	Shell/bedrock (crevices)	1	0.00	0.00	0.00	0.00

Table 14d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 1999 survey (Plumper Islands only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD; Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	49	0.06	0.69	0.76	0.70 ± 0.25
128	Bedrock (smooth)/bedrock (crevices)/shell	2	0.00	0.00	0.00	
130	Bedrock (smooth)/boulders	2	0.00	0.00	0.00	
200	Bedrock (crevices)	66	0.14	1.77	1.91	2.04 ± 0.44
230	Bedrock (crevices)/boulders	3	0.00	7.33	7.33	
240	Bedrock (crevices)/cobble	2	0.00	2.00	2.00	
280	Bedrock (crevices)/shell	4	0.00	0.25	0.25	
325	Boulders/bedrock (crevices)/ gravel	1	0.00	1.00	1.00	0.79 ± 0.43
340	Boulders/cobble	3	0.00	0.33	0.33	
380	Boulders/shell	10	0.10	0.80	0.90	
458	Cobble/gravel/shell	4	0.25	0.75	1.00	1.00 ± 1.00
800	Shell	2	0.00	0.00	0.00	0.13 ± 0.09
850	Shell/gravel	13	0.00	0.15	0.15	
854	Shell/gravel/cobble	1	0.00	0.00	0.00	

Table 15. Summary results of measurements taken during green urchin dissections from the November, 1999 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. SE = Standard Error; Gutted Weight = stomach and contents removed; Gonad Texture: 0=unknown or no sample, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or no sample, 1=firm, 2=semi-firm, 3=flimsy; Sex: 1=male, 2=female, 3=juvenile or unknown). Sample Size is for all calculations.

Summary Information			**LOCATION**								
			STEPHENSON ISLETS			**STUBBS ISLAND**			**PLUMPER ISLANDS**		
			Legal	**Sublegal-mature**	**Sublegal–immature**	**Legal**	**Sublegal–mature**	**Sublegal-immature**	**Legal**	**Sublegal-mature**	**Sublegal-immature**
Sample Size			30	49	4	17	18	2	11	26	1
Mean Test Height (mm) ± SE			33.1 (± 0.7)	21.1 (± 0.7)	11.0 (± 2.0)	34.9 (± 0.9)	18.7 (± 1.6)	10.0 (± 0.0)	33.2 (± 1.7)	20.1 (± 0.8)	10.0
Mean Test Diameter (mm) ± SE			62.9 (± 1.0)	41.2 (± 1.2)	17.5 (± 2.3)	67.2 (± 1.2)	41.1 (± 2.0)	19.5 (± 2.5)	65.1 (± 2.2)	38.1 (± 1.4)	20.0
Mean Total Wet Weight (g) ± SE			88.66 (± 4.26)	29.12 (± 2.17)	4.18 (± 1.55)	108.39 (± 5.17)	27.58 (± 3.24)	3.80 (± 1.30)	101.06 (± 10.97)	25.03 (± 2.45)	4.60
Mean Drained Weight (g) ± SE			69.64 (± 3.30)	24.75 (± 1.77)	3.85 (± 1.47)	86.56 (± 4.05)	23.99 (± 2.76)	3.40 (± 1.20)	75.28 (± 6.57)	21.10 (± 1.92)	4.20
Mean Gutted Weight (g) ± SE			55.45 (± 2.93)	18.84 (± 1.37)	2.88 (± 1.05)	67.84 (± 2.97)	18.81 (± 2.34)	2.55 (± 0.95)	58.35 (± 5.44)	16.38 (± 1.65)	3.00
Mean Stomach and Content Weight (g) ± SE			14.19 (± 0.83)	5.91 (± 0.46)	0.98 (± 0.43)	18.72 (± 1.68)	5.18 (± 0.53)	0.85 (± 0.25)	16.93 (± 1.70)	4.73 (± 0.39)	1.20
Sex	% Male		50	10	0	35	17	0	18	15	0
	% Female		50	65	0	65	61	0	82	54	0
	% Unknown		0	25	100	0	22	100	0	23	100
Gonad	Mean Weight (g) ± SE		13.70 (± 1.25)	2.80 (± 0.45)	0.15 (± 0.15)	19.22 (± 1.40)	3.79 (± 0.81)	0	12.95 (± 1.34)	2.42 (± 0.51)	0
	Colour Proportion	0	0	0.14	0.75	0	0	1.00	0	0.15	1.00
		1	0.83	0.78	0.25	0.76	1.00	0	0.91	0.77	0
		2	0.13	0.06	0	0.18	0	0	0	0.08	0
		3	0.03	0.02	0	0.06	0	0	0.09	0	0
	Texture Proportion	0	0	0.14	0.75	0	0	1.00	0	0.15	1.00
		1	0.60	0.49	0	0.59	0.22	0	0.73	0.42	0
		2	0.37	0.37	0.25	0.41	0.78	0	0.18	0.42	0
		3	0.03	0	0	0	0	0	0.09	0	0

Table 16. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in November, 1999 (excluding biomass of unknowns, but very few unknowns in this survey). (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured).

Size Category	**Stephenson Islets**	**Stubbs Island**	**Plumper Islands**
Number of Legal-sized	984,441 ± 240,675	64,814 ± 16,834	19,323 ± 4,877
Number of Sublegal-mature	1,628,774 ± 261,025	68,600 ± 16,813	200,136 ± 92,058
Number of Sublegal-immature	293,304 ± 40,716	13,364 ± 4,966	66,252 ± 43,365
Number of Unknown	3,120 ± 2,961	0	0
Number of all sizes	2,909,640 ± 349,493	146,777 ± 34,888	285,711 ± 95,932
Biomass of Legal-size (t)	79.22 ± 19.37	6.05 ± 1.57	1.77 ± 0.46
Biomass of Sublegal-mature (t)	41.57 ± 6.67	1.73 ± 0.42	3.21 ± 1.49
Biomass of Sublegal-immature (t)	0.95 ± 0.13	0.05 ± 0.02	0.24 ± 0.16
Total Biomass (t) (excludes Unknowns)	121.74 ± 20.49	7.82 ± 1.63	5.22 ± 1.56

Table 17. Means and standard errors (SE) of test diameters (TD) (using November, 2000 field survey data) and weight (using TD-total wet weight relationships from November, 2000 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	846	61.1	0.2	78.8	0.7
	Sublegal-Mature	1892	42.5	0.2	31.2	0.3
	Sublegal-Immature	188	17.2	0.4	3.0	0.1
Stephenson Islets	Legal	427	60.3	0.2	75.9	0.9
	Sublegal-Mature	1201	42.5	0.2	30.9	0.4
	Sublegal-Immature	114	15.6	0.5	2.5	0.2
Stubbs Island	Legal	207	62.6	0.5	84.8	1.9
	Sublegal-Mature	318	45.5	0.4	36.8	0.8
	Sublegal-Immature	42	19.0	0.6	3.6	0.3
Plumper Islands	Legal	212	61.1	0.4	78.8	1.5
	Sublegal-Mature	373	40.3	0.5	27.7	0.8
	Sublegal-Immature	32	20.2	0.7	4.1	0.3

Table 18. Sample mean densities (urchins/m^2) by transect and overall standard errors for green sea urchins of legal size, sublegal size, unknown size, and all sizes (total) in the November, 2000 survey. (Legal = ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 15 to 17, and Plumper Islands = Transects 20 to 23[1].

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	17 M 27 T	0.26 (0.44)	0.89 (1.59)	0.19 (0.33)	1.04 (0.00)	2.37
5A	29	0.79	3.45	0.38	0.00	4.62
6	41	0.76	1.02	0.10	0.00	1.88
7	62	1.68	2.21	0.13	0.00	4.02
8	18	1.22	1.17	0.39	0.00	2.78
9	48	1.23	5.48 (5.50)	0.35	0.02 (0.00)	7.08
11	24	1.54	1.29	0.08	0.00	2.92
13	34	1.15	8.62	1.06	0.00	10.82
14	58	1.17	3.48	0.29	0.00	4.95
Stephenson Islets Totals	331 M 341 T	1.14 ± 0.14 (1.16 ± 0.14)	3.26 ± 0.78 (3.32 ± 0.78)	0.31 ± 0.10 (0.33 ± 0.10)	0.09 ± 0.09 (0.00)	4.81 ± 0.87
15	17	2.29	5.06	0.29	0.00	7.65
16	18	3.44	2.72	0.72	0.00	6.89
17	29	3.31	5.03	0.79	0.00	9.14
Stubbs Island Totals	64	3.08 ± 0.31	4.39 ± 0.71	0.64 ± 0.14	0.00	8.11 ± 0.73
20	44	1.36	2.82	0.27	0.00	4.45
21	31	3.19	4.00	0.23	0.00	7.42
22	36	1.44	3.25	0.33	0.00	5.03
23	13	0.00	0.31	0.00	0.00	0.31
Plumper Islands Totals	124	1.70 ± 0.51	2.98 ± 0.45	0.25 ± 0.04	0.00	4.93 ± 0.93
OVERALL TOTAL	519 M 529 T	1.51 ± 0.20 (1.52 ± 0.20)	3.33 ± 0.51 (3.37 ± 0.51)	0.34 ± 0.07 (0.35 ± 0.0[illegible])	0.05 ± 0.05 (0.00)	5.23 ± 0.64

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[1] The numbers in the brackets indicate calculations where the unknowns have been proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and assigning a zero value to the unknowns. M=measured quadrats; T=total quadrats (measured and counted).

Table 19a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD from all survey sites combined in the November, 2000 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	**Depth Range (m)**	**Number of Quadrats**	**Legal Density**	**Sublegal Density**	**Total Density**
-3 to 0	-0.9 to 0.0	24	3.00	8.29	11.29 ± 2.17
1 to 5	0.3 to 1.5	45	2.98	6.11	9.09 ± 1.29
6 to 10	1.8 to 3.0	67	2.39	6.12	8.51 ± 1.25
11 to 15	3.3 to 4.8	78	3.01	5.78	8.79 ± 0.78
16 to 20	4.9 to 6.1	63	1.62	2.94	4.56 ± 0.62
21 to 25	6.4 to 7.6	96	0.91	2.48	3.39 ± 0.44
26 to 30	7.9 to 9.1	105	0.48	2.45	2.92 ± 0.49
31 to 35	9.4 to 10.7	73	0.16	1.12	1.29 ± 0.25
36 to 37	11.0 to 11.3	7	0.00	0.86	0.86 ± 0.46

Table 19b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Stephenson Islets in the November, 2000 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	**Depth Range (m)**	**Number of Quadrats**	**Legal Density**	**Sublegal Density**	**Total Density**
-2 to 0	-0.6 to 0.0	12	4.58	10.58	15.17 ± 3.66
1 to 5	0.3 to 1.5	23	2.39	6.13	8.52 ± 2.15
6 to 10	1.8 to 3.0	32	2.44	8.09	10.53 ± 2.03
11 to 15	3.3 to 4.8	44	2.73	5.23	7.95 ± 1.21
16 to 20	4.9 to 6.1	41	1.34	2.63	3.98 ± 0.67
21 to 25	6.4 to 7.6	72	0.46	2.51	2.97 ± 0.45
26 to 30	7.9 to 9.1	83	0.34	2.78	3.12 ± 0.54
31 to 35	9.4 to 10.7	38	0.18	1.50	1.68 ± 0.42
36 to 37	11.0 to 11.3	5	0.00	1.20	1.20 ± 0.58

Table 19c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD at Stubbs Island in the November, 2000 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. No unmeasured urchins).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Total Density
-3 to 0	-0.9 to 0.0	10	1.70	7.10	8.80 ± 1.98
1 to 5	0.3 to 1.5	12	4.58	7.33	11.92 ± 1.38
6 to 10	1.8 to 3.0	13	3.69	4.92	8.62 ± 0.79
11 to 15	3.3 to 4.8	13	4.08	6.77	10.85 ± 1.16
16 to 20	4.9 to 6.1	5	2.60	2.60	5.20 ± 2.35
21 to 25	6.4 to 7.6	5	2.60	2.00	4.60 ± 2.93
26 to 30	7.9 to 9.1	6	0.83	2.00	2.83 ± 1.49
31 to 35	9.4 to 10.7	8	0.38	1.75	2.13 ± 0.74

Table 19d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Plumper Islands in the November, 2000 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. No unmeasured urchins).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
0.0	0.0	2	0.00	0.50	0.50 ± 0.50
1 to 5	0.3 to 1.5	10	2.40	4.60	7.00 ± 2.52
6 to 10	1.8 to 3.0	22	1.55	3.95	5.50 ± 2.26
11 to 15	3.3 to 4.8	21	2.95	6.33	9.29 ± 1.18
16 to 20	4.9 to 6.1	17	2.00	3.76	5.76 ± 1.47
21 to 25	6.4 to 7.6	19	2.05	2.58	4.63 ± 1.21
26 to 30	7.9 to 9.1	16	1.06	0.88	1.94 ± 1.49
31 to 35	9.4 to 10.7	27	0.07	0.41	0.48 ± 0.18
36	11.0	2	0.00	0.00	0.00

Table 20a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 2000 survey (all areas combined). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured; Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	195	1.39	3.37	0.00	4.76	4.76 ± 0.37
120	Bedrock (smooth)/bedrock (crevices)	62	1.26	2.82	0.03	4.11	
123	Bedrock (smooth)/bedrock (crevices)/boulders	4	0.25	3.75	0.00	4.00	
124	Bedrock (smooth)/bedrock (crevices)/cobble	3	1.33	3.67	0.00	5.00	
128	Bedrock (smooth)/bedrock (crevices)/shell	2	0.50	2.00	0.00	2.50	
130	Bedrock (smooth)/boulders	16	2.19	4.81	0.00	7.00	
134	Bedrock (smooth)/boulders/cobble	2	2.00	5.00	0.00	7.00	
138	Bedrock (smooth)/boulders/shell	6	0.17	1.33	0.00	1.50	
140	Bedrock (smooth)/cobble	5	1.00	2.80	0.00	3.80	
150	Bedrock (smooth)/gravel	2	9.50	21.50	0.00	31.00	
160	Bedrock (smooth)/pea gravel	1	0.00	0.00	0.00	0.00	
180	Bedrock (smooth)/shell	5	0.20	1.40	0.00	1.60	
183	Bedrock (smooth)/shell/boulders	1	1.00	2.00	0.00	3.00	
185	Bedrock (smooth)/shell/gravel	1	0.00	4.00	0.00	4.00	
200	Bedrock (crevices)	41	2.66	6.76	0.00	9.41	7.73 ± 0.74
210	Bedrock (crevices)/bedrock (smooth)	32	2.25	3.47	0.44	6.16	
230	Bedrock (crevices)/boulders	2	0.00	0.50	1.00	1.50	
240	Bedrock (crevices)/cobble	1	0.00	0.00	0.00	0.00	
280	Bedrock (crevices)/shell	1	2.00	14.00	0.00	16.00	
285	Bedrock (crevices)/shell/gravel	1	0.00	0.00	1.00	1.00	
300	Boulders	42	3.14	6.62	0.00	9.76	7.21 ± 1.01
310	Boulders/bedrock (smooth)	2	0.50	5.50	0.00	6.00	
312	Boulders/bedrock (smooth)/bedrock (crevices)	3	0.00	1.00	0.00	1.00	
314	Boulders/bedrock (smooth)/cobble	3	0.00	1.67	0.00	1.67	
315	Boulders/bedrock (smooth)/gravel	1	0.00	0.00	0.00	0.00	
318	Boulders/bedrock (smooth)/shell	2	0.50	3.50	0.00	4.00	
321	Boulders/bedrock (crevices)/bedrock (smooth)	2	1.00	2.50	0.50	4.00	
340	Boulders/cobble	11	1.00	7.36	0.00	8.36	
341	Boulders/cobble/bedrock (smooth)	1	0.00	5.00	0.00	5.00	
342	Boulders/cobble/bedrock (crevices)	2	0.00	2.00	1.00	3.00	
345	Boulders/cobble/gravel	2	1.00	3.00	0.00	4.00	
348	Boulders/cobble/shell	2	1.00	5.50	0.00	6.50	
350	Boulders/gravel	5	2.60	1.20	0.00	3.80	
380	Boulders/shell	7	0.57	2.86	0.00	3.43	

Table 20a. (continued)

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
400	Cobble	13	0.77	2.23	0.15	3.15	2.47 ± 0.74
421	Cobble/bedrock (crevices)/bedrock (smooth)	2	1.00	1.50	0.00	2.50	
430	Cobble/boulders	3	0.67	1.33	0.00	2.00	
438	Cobble/boulders/shell	2	0.00	0.50	0.00	0.50	
450	Cobble/gravel	7	1.00	1.14	0.00	2.14	
451	Cobble/bedrock (smooth)	1	0.00	1.00	0.00	1.00	
458	Cobble/gravel/shell	1	0.00	0.00	5.00	5.00	
485	Cobble/shell/gravel	1	0.00	0.00	0.00	0.00	
500	Gravel	12	0.17	0.83	0.00	1.00	1.10 ± 0.32
510	Gravel/bedrock (smooth)	1	1.00	2.00	0.00	3.00	
530	Gravel/boulders	2	0.00	3.00	0.00	3.00	
540	Gravel/cobble	3	0.00	0.00	0.00	0.00	
581	Gravel/shell/bedrock (smooth)	1	0.00	1.00	0.00	1.00	
584	Gravel/shell/cobble	1	0.00	0.00	0.00	0.00	
813	Shell/bedrock (smooth)/boulders	1	0.00	1.00	0.00	1.00	0.55 ± 0.21
830	Shell/boulders	1	0.00	1.00	0.00	1.00	
840	Shell/cobble	5	0.20	0.40	0.00	0.60	
850	Shell/gravel	4	0.00	0.25	0.00	0.25	

Table 20b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 2000 survey (Stephenson Islets only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured; Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	114	0.92	2.75	0.00	3.67	3.81 ± 0.43
120	Bedrock (smooth)/bedrock (crevices)	58	1.22	2.95	0.03	4.21	
123	Bedrock (smooth)/bedrock (crevices)/boulders	4	0.25	3.75	0.00	4.00	
124	Bedrock (smooth)/bedrock (crevices)/cobble	3	1.33	3.67	0.00	5.00	
128	Bedrock (smooth)/bedrock (crevices)/shell	2	0.50	2.00	0.00	2.50	
130	Bedrock (smooth)/boulders	1	0.00	1.00	0.00	1.00	
138	Bedrock (smooth)/boulders/shell	1	0.00	2.00	0.00	2.00	
140	Bedrock (smooth)/cobble	4	0.50	2.00	0.00	2.50	
180	Bedrock (smooth)/shell	1	0.00	6.00	0.00	6.00	
200	Bedrock (crevices)	31	1.45	7.58	0.00	9.03	7.31 ± 0.80
210	Bedrock (crevices)/bedrock (smooth)	32	2.25	3.47	0.44	6.16	
230	Bedrock (crevices)/boulders	2	0.00	0.50	1.00	1.50	
240	Bedrock (crevices)/cobble	1	0.00	0.00	0.00	0.00	
280	Bedrock (crevices)/shell	1	2.00	14.00	0.00	16.00	
285	Bedrock (crevices)/shell/gravel	1	0.00	0.00	1.00	1.00	
300	Boulders	19	3.11	7.95	0.00	11.05	7.31 ± 1.60
310	Boulders/bedrock (smooth)	1	0.00	5.00	0.00	5.00	
312	Boulders/bedrock (smooth)/bedrock (crevices)	3	0.00	1.00	0.00	1.00	
314	Boulders/bedrock (smooth)/cobble	3	0.00	1.67	0.00	1.67	
315	Boulders/bedrock (smooth)/gravel	1	0.00	0.00	0.00	0.00	
318	Boulders/bedrock (smooth)/shell	2	0.50	3.50	0.00	4.00	
321	Boulders/bedrock (crevices)/ bedrock (smooth)	2	1.00	2.50	0.50	4.00	
340	Boulders/cobble	8	1.00	8.88	0.00	9.88	
341	Boulders/cobble/bedrock (smooth)	1	0.00	5.00	0.00	5.00	
342	Boulders/cobble/bedrock (crevices)	2	0.00	2.00	1.00	3.00	
348	Boulders/cobble/shell	2	1.00	5.50	0.00	6.50	
350	Boulders/gravel	1	0.00	2.00	0.00	2.00	
380	Boulders/shell	3	0.00	2.33	0.00	2.33	

Table 20b. (continued)

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
400	Cobble	12	0.83	2.25	0.17	3.25	2.29 ± 0.90
421	Cobble/bedrock (smooth)/bedrock (crevices)	1	0.00	0.00	0.00	0.00	
430	Cobble/boulders	3	0.67	1.33	0.00	2.00	
438	Cobble/boulders/shell	2	0.00	0.50	0.00	0.50	
450	Cobble/gravel	3	0.33	0.67	0.00	1.00	
451	Cobble/gravel/bedrock (smooth)	1	0.00	1.00	0.00	1.00	
458	Cobble/gravel/shell	1	0.00	0.00	5.00	5.00	
485	Cobble/shell/gravel	1	0.00	0.00	0.00	0.00	
500	Gravel	8	0.13	1.00	0.00	1.13	1.46 ± 0.45
510	Gravel/bedrock (smooth)	1	1.00	2.00	0.00	3.00	
530	Gravel/boulders	2	0.00	3.00	0.00	3.00	
581	Gravel/shell/bedrock (smooth)	1	0.00	1.00	0.00	1.00	
584	Gravel/shell/cobble	1	0.00	0.00	0.00	0.00	

Table 20c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 2000 survey (Stubbs Island only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD; Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	31	3.35	6.10	9.45	8.19 ± 0.78
120	Bedrock (smooth)/bedrock (crevices)	4	1.75	1.00	2.75	
130	Bedrock (smooth)/boulders	14	2.14	4.93	7.07	
134	Bedrock (smooth)/boulders/cobble	2	2.00	5.00	7.00	
140	Bedrock (smooth)/cobble	1	3.00	6.00	9.00	
200	Bedrock (crevices)	8	5.75	4.00	9.75	9.75 ± 1.31
340	Boulders/cobble	1	0.00	5.00	5.00	4.00 ± 1.00
345	Boulders/cobble/gravel	1	1.00	2.00	3.00	
400	Cobble	1	0.00	2.00	2.00	3.50 ± 1.50
421	Cobble/bedrock (crevices)/bedrock (smooth)	1	2.00	3.00	5.00	

Table 20d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the November, 2000 survey (Plumper Islands only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD; Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	50	1.26	3.10	4.36	4.74 ± 0.94
130	Bedrock (smooth)/boulders	1	5.00	7.00	12.00	
138	Bedrock (smooth)/boulders/ shell	5	0.20	1.20	1.40	
150	Bedrock (smooth)/gravel	2	9.50	21.50	31.00	
160	Bedrock (smooth)/pea gravel	1	0.00	0.00	0.00	
180	Bedrock (smooth)/shell	4	0.25	0.25	0.50	
183	Bedrock (smooth)/shell/ boulders	1	1.00	2.00	3.00	
185	Bedrock (smooth)/shell/gravel	1	0.00	4.00	4.00	
200	Bedrock (crevices)	2	9.00	5.00	14.00	14.00±10.00
300	Boulders	23	3.17	5.52	8.70	7.26 ± 1.13
310	Boulders/bedrock (smooth)	1	1.00	6.00	7.00	
340	Boulders/cobble	2	1.50	2.50	4.00	
345	Boulders/cobble/gravel	1	1.00	4.00	5.00	
350	Boulders/gravel	4	3.25	1.00	4.25	
380	Boulders/shell	4	1.00	3.25	4.25	
450	Cobble/gravel	4	1.50	1.50	3.00	3.00 ± 1.22
500	Gravel	4	0.25	0.50	0.75	0.43 ± 0.30
540	Gravel/cobble	3	0.00	0.00	0.00	
813	Shell/bedrock (smooth)/ boulders	1	0.00	1.00	1.00	0.55 ± 0.21
830	Shell/boulders	1	0.00	1.00	1.00	
840	Shell/cobble	5	0.20	0.40	0.60	
850	Shell/gravel	4	0.00	0.25	0.25	

Table 21. Summary results of measurements taken during green urchin dissections from the November, 2000 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. SE = Standard Error; *Gutted Weight = stomach contents removed only; Gonad Texture: 0=unknown or no sample, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or no sample, 1=firm, 2=semi-firm, 3=flimsy; Sex: 1=male, 2=female, 3=juvenile or unknown). Sample Size is for all calculations.

Summary Information			**LOCATION**								
			STEPHENSON ISLETS			**STUBBS ISLAND**			**PLUMPER ISLANDS**		
			Legal	**Sublegal-mature**	**Sublegal–immature**	**Legal**	**Sublegal–mature**	**Sublegal–immature**	**Legal**	**Sublegal-mature**	**Sublegal–immature**
Sample Size			31	39	0	12	13	0	15	13	0
Mean Test Height (mm) ± SE			33.4 (± 1.0)	22.7 (± 0.7)	0	32.2 (± 1.4)	23.6 (± 0.8)	0	30.1 (± 1.2)	21.7 (± 1.2)	0
Mean Test Diameter (mm) ± SE			63.4 (± 1.3)	43.6 (± 1.1)	0	64.6 (± 2.3)	47.8 (± 1.1)	0	63.1 (± 1.9)	45.1 (± 1.9)	0
Mean Total Wet Weight (g) ± SE			88.41 (± 5.22)	31.82 (± 2.07)	0	89.93 (± 7.77)	38.80 (± 2.38)	0	85.15 (± 8.28)	34.36 (± 3.93)	0
Mean Drained Weight (g) ± SE			67.27 (± 3.55)	26.14 (± 1.74)	0	73.22 (± 6.12)	31.97 (± 1.94)	0	64.81 (± 5.63)	28.28 (± 3.23)	0
*Mean Gutted Weight (g) ± SE			52.88 (± 2.92)	20.38 (± 1.41)	0	60.69 (± 4.88)	26.14 (± 1.67)	0	52.99 (± 4.02)	22.36 (± 2.96)	0
*Mean Stomach Content Weight (g) ± SE			14.39 (± 0.99)	5.76 (± 0.41)	0	12.53 (± 1.99)	5.83 (± 0.69)	0	11.83 (± 1.87)	5.92 (± 0.66)	0
Sex	% Male		48	28	0	25	38	0	40	46	0
	% Female		48	46	0	75	62	0	60	46	0
	% Unknown		3	26	0	0	0	0	0	8	0
Gonad	Mean Weight (g) ± SE		11.33 (± 1.06)	3.39 (± 0.45)	0	17.88 (± 1.81)	7.11 (± 1.58)	0	13.20 (± 1.28)	4.17 (± 1.15)	0
	Colour Proportion	0	0	0.03	0	0	0	0	0	0.08	0
		1	0.61	0.79	0	0.92	0.85	0	0.80	0.85	0
		2	0.35	0.18	0	0.08	0.15	0	0.20	0.08	0
		3	0.03	0	0	0	0	0	0	0	0
	Texture Proportion	0	0	0.03	0	0	0	0	0	0.08	0
		1	0.87	0.79	0	0.92	0.85	0	0.93	0.85	0
		2	0.13	0.18	0	0.08	0.15	0	0.07	0.08	0
		3	0	0	0	0	0	0	0	0	0

Table 22. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in November, 2000 (incorporates estimates from unknowns). (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Size Category	**Stephenson Islets**	**Stubbs Island**	**Plumper Islands**
Number of Legal-sized	562,035 ± 65,606	60,331 ± 6,123	380,481 ± 112,809
Number of Sublegal-mature	1,612,116 ± 379,217	86,056 ± 13,931	665,390 ± 101,081
Number of Sublegal-immature	157,939 ± 48,174	12,556 ± 2,817	55,900 ± 9,570
Number of all sizes	2,332,090 ± 422,646	158,944 ± 14,204	1,101,771 ± 208,430
Biomass of Legal-size (t)	42.63 ± 4.98	5.12 ± 0.52	29.97 ± 8.90
Biomass of Sublegal-mature (t)	49.75 ± 11.71	3.16 ± 0.51	18.44 ± 2.82
Biomass of Sublegal-immature (t)	0.39 ± 0.12	0.05 ± 0.01	0.23 ± 0.04
Total Biomass (t)	92.78 ± 12.73	8.33 ± 0.73	48.64 ± 9.33

Table 23. Means and standard errors (SE) of test diameters (TD) (using November, 2001 field survey data) and weight (using TD-total wet weight relationships from November, 2001 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	1413	61.4	0.1	83.9	0.6
	Sublegal-Mature	2345	43.0	0.2	32.5	0.3
	Sublegal-Immature	141	18.7	0.4	3.3	0.2
Stephenson Islets	Legal	797	60.4	0.2	79.6	0.7
	Sublegal-Mature	1771	43.3	0.2	32.7	0.3
	Sublegal-Immature	115	18.3	0.5	3.2	0.2
Stubbs Island	Legal	409	62.8	0.3	89.6	1.3
	Sublegal-Mature	325	43.0	0.5	33.1	0.9
	Sublegal-Immature	11	19.6	1.6	3.7	0.6
Plumper Islands	Legal	207	62.7	0.4	88.8	1.7
	Sublegal-Mature	249	41.4	0.6	30.2	1.0
	Sublegal-Immature	15	21.0	0.7	4.1	0.3

Table 24. Sample mean densities (number/m^2) by transect for green sea urchins of legal size, sublegal size, unknown size, and all sizes (total) in the November, 2001 survey. (Legal = ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 15 to 18, and Plumper Islands = Transects 20 to 23[2].

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	74	2.14	1.28	0.12	0.00	3.54
5A	17 M 33 T	1.24 (2.33)	1.85 (3.48)	0.03 (0.06)	2.76 (0.00)	5.88
6	24	3.58	7.92	0.04	0.00	11.54
7	38 M 46T	1.80 (2.15)	1.59 (1.89)	0.15 (0.17)	0.67 (0.00)	4.22
8	16	1.00	0.81	0.00	0.00	1.81
9	86	0.77	5.91 (5.92)	0.56	0.01 (0.00)	7.24
10	18 M 32 T	0.81 (1.38)	0.56 (0.97)	0.06 (0.09)	1.00 (0.00)	2.44
11	37	4.81	5.08	0.27	0.00	10.16
13	42	0.93	6.19	0.52	0.00	7.64
14	45	0.96	3.89	0.31	0.00	5.16
Stephenson Islets Totals or Avg.	397 M 435 T	1.69 ± 0.39 (1.80 ± 0.39)	3.63 ± 0.83 (3.87 ± 0.80)	0.26 ± 0.08 (0.26 ± 0.08)	0.36 ± 0.23 (0.00)	5.94 ± 0.83
15	9 M 17 T	3.35 (6.94)	1.88 (3.88)	0.12 (0.24)	5.71 (0.00)	11.06
16	16	9.00	4.31	0.13	0.00	13.44
17	35	4.29	5.31	0.11	0.00	9.71
18	18	2.50	1.22	0.11	0.00	3.83
Stubbs Island Totals or Avg.	78 M 86 T	4.60 ± 1.12 (5.23 ± 1.20)	3.59 ± 1.08 (4.08 ± 0.90)	0.12 ± 0.002 (0.14 ± 0.03)	1.13 ± 1.23 (0.00)	9.44 ± 1.65
20	18 M 37 T	1.89 (4.92)	1.62 (4.24)	0.05 (0.14)	5.73 (0.00)	9.30
21	27	2.26	2.74 (2.78)	0.04	0.04 (0.00)	5.07
22	29	2.41	3.66	0.34	0.00	6.41
23	16	0.31	0.44	0.00	0.00	0.75
Plumper Islands Totals or Avg.	90 M 109 T	1.89 ± 0.33 (2.75 ± 0.96)	2.27 ± 0.60 (3.30 ± 0.64)	0.12 ± 0.08 (0.15 ± 0.07)	1.95 ± 1.72 (0.00)	6.23 ± 1.56
OVERALL TOTAL	565 M 630 T	2.12 ± 0.37 (2.40 ± 0.43)	3.39 ± 0.60 (3.83 ± 0.56)	0.22 ± 0.06 (0.23 ± 0.06)	0.74 ± 0.39 (0.00)	6.47 ± 0.69

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[2] The numbers in the brackets indicate calculations where the unknowns have been proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and assigning a zero value to the unknowns. M=measured quadrats; T=total quadrats (measured and counted).

Table 25a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD from all survey sites combined in the November, 2001 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-8 to -5	-2.4 to -1.5	7	0.43	0.29	0.71 ± 0.71
-4 to 0	-1.2 to 0.0	47	2.89	9.89	12.79 ± 3.99
1 to 5	0.3 to 1.5	74	4.41	6.99	11.39 ± 1.43
6 to 10	1.8 to 3.0	88	4.42	5.32	9.74 ± 1.12
11 to 15	3.3 to 4.8	114	2.69	3.68	6.38 ± 0.67
16 to 20	4.9 to 6.1	85	1.58	3.99	5.56 ± 0.90
21 to 25	6.4 to 7.6	113	1.20	2.46	3.66 ± 0.48
26 to 30	7.9 to 9.1	85	0.81	1.75	2.56 ± 0.40
31 to 35	9.4 to 10.7	52	1.94	3.33	5.27 ± 0.89

Table 25b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Stephenson Islets in the November, 2001 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-8 to -5	-2.4 to -1.5	7	0.43	0.29	0.71 ± 0.71
-4 to 0	-1.2 to 0.0	32	2.84	11.16	14.00 ± 5.67
1 to 5	0.3 to 1.5	46	3.35	8.35	11.70 ± 1.95
6 to 10	1.8 to 3.0	61	3.92	5.46	9.38 ± 1.21
11 to 15	3.3 to 4.8	86	1.78	3.36	5.14 ± 0.65
16 to 20	4.9 to 6.1	61	1.02	4.15	5.16 ± 0.85
21 to 25	6.4 to 7.6	80	0.69	2.40	3.09 ± 0.52
26 to 30	7.9 to 9.1	56	0.34	1.52	1.86 ± 0.31
31 to 35	9.4 to 10.7	32	2.25	3.13	5.38 ± 1.24

Table 25c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD at Stubbs Island in the November, 2001 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Total Density
-3 to 0	-0.9 to 0.0	9	4.33	8.78	13.11 ± 5.23
1 to 5	0.3 to 1.5	16	10.06	7.63	17.69 ± 2.43
6 to 10	1.8 to 3.0	16	8.31	7.00	15.31 ± 3.61
11 to 15	3.3 to 4.8	13	6.62	2.85	9.46 ± 1.73
16 to 20	4.9 to 6.1	10	2.00	2.00	4.00 ± 0.86
21 to 25	6.4 to 7.6	10	1.70	0.60	2.30 ± 0.93
26 to 30	7.9 to 9.1	11	1.36	1.09	2.45 ± 1.14
31 to 33	9.4 to 10.1	7	1.14	2.43	3.57 ± 1.73

Table 25d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Plumper Islands in the November, 2001 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-2 to 0	-0.6 to 0.0	6	1.83	4.00	5.83 ± 3.23
1 to 5	0.3 to 1.5	12	1.08	0.75	1.83 ± 0.73
6 to 10	1.8 to 3.0	11	1.82	1.82	3.64 ± 1.36
11 to 15	3.3 to 4.8	15	4.67	6.13	10.80 ± 2.84
16 to 20	4.9 to 6.1	14	4.86	3.57	8.43 ± 3.98
21 to 25	6.4 to 7.6	23	3.09	3.17	6.26 ± 1.38
26 to 30	7.9 to 9.1	18	2.11	2.72	4.83 ± 1.38
31 to 33	9.4 to 10.1	13	1.69	4.23	5.92 ± 1.65

Table 26a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 2001 survey (all areas combined). (Legal ≥ 55 mm TD, Sublegal < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type. Unknown substrate type = no information recorded).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
000	Unknown	303	1.77	2.40	0.52	4.68	4.68 ± 0.40
100	Bedrock (smooth)	89	1.07	1.84	1.24	4.15	6.11 ± 0.86
120	Bedrock (smooth)/bedrock (crevices)	4	4.25	2.75	18.25	25.25	
130	Bedrock (smooth)/boulders	8	2.75	2.75	5.75	11.25	
140	Bedrock (smooth)/cobble	4	7.50	4.50	2.50	14.50	
148	Bedrock (smooth)/cobble/shell	1	0.00	30.00	0.00	30.00	
200	Bedrock (crevices)	152	2.13	6.49	0.32	8.94	9.06 ± 1.23
230	Bedrock (crevices)/boulders	14	6.57	2.43	0.00	9.00	
234	Bedrock (crevices)/boulders/ cobble	1	12.00	26.00	0.00	38.00	
240	Bedrock (crevices)/cobble	4	1.25	7.75	0.00	9.00	
248	Bedrock (crevices)/cobble/ shell	1	0.00	2.00	0.00	2.00	
280	Bedrock (crevices)/shell	1	0.00	6.00	0.00	6.00	
300	Boulders	15	2.80	3.00	0.40	6.20	9.72 ± 1.93
320	Boulders/bedrock (crevices)	2	26.00	18.50	0.00	44.50	
340	Boulders/cobble	8	3.50	4.38	1.63	9.50	
348	Boulders/cobble/shell	2	9.50	4.50	0.00	14.00	
360	Boulders/pea gravel	4	0.75	1.75	0.00	2.50	
380	Boulders/shell	1	14.00	1.00	0.00	15.00	
400	Cobble	11	4.27	6.18	0.09	10.55	10.55 ± 2.24
560	Gravel/pea gravel	2	0.50	3.00	0.00	3.50	3.33 ± 2.03
570	Gravel/sand	1	0.00	3.00	0.00	3.00	
700	Sand	1	0.00	0.00	0.00	0.00	0.00
800	Shell	1	0.00	6.00	0.00	6.00	3.00 ± 3.00
810	Shell/bedrock (creviced)	1	0.00	0.00	0.00	0.00	

Table 26b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 2001 survey (Stephenson Islets only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
000	Unknown	257	1.42	2.12	0.46	4.00	4.00 ± 0.40
100	Bedrock (smooth)	35	0.89	2.83	0.23	3.94	4.57 ± 1.05
140	Bedrock (smooth)/cobble	1	1.00	0.00	0.00	1.00	
148	Bedrock (smooth)/cobble/ shell	1	0.00	30.00	0.00	30.00	
200	Bedrock (crevices)	130	2.40	7.41	0.22	10.02	9.99 ± 1.53
240	Bedrock (crevices)/cobble	4	1.25	7.75	0.00	9.00	
300	Boulders	1	1.00	0.00	0.00	1.00	7.00 ± 2.00
340	Boulders/cobble	5	3.80	4.40	0.00	8.20	
400	Cobble	1	3.00	2.00	0.00	5.00	5.00 ± 0.00
570	Gravel/sand	1	0.00	3.00	0.00	3.00	3.00 ± 0.00

Table 26c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 2001 survey (Stubbs Island only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
000	Unknown	31	4.74	4.61	1.23	10.58	10.58 ± 1.66
100	Bedrock (smooth)	16	2.13	2.06	1.13	5.31	6.65 ± 1.44
120	Bedrock (smooth)/bedrock (crevices)	3	5.67	3.67	8.00	17.33	
130	Bedrock (smooth)/boulders	3	0.00	0.33	1.33	1.67	
140	Bedrock (smooth)/cobble	1	4.00	7.00	0.00	11.00	
200	Bedrock (crevices)	8	0.13	0.50	0.00	0.63	7.08 ± 2.12
230	Bedrock (crevices)/boulders	14	6.57	2.43	0.00	9.00	
234	Bedrock (crevices)/boulders/ cobble	1	12.00	26.00	0.00	38.00	
248	Bedrock (crevices)/cobble/ shell	1	0.00	2.00	0.00	2.00	
280	Bedrock (crevices)/shell	1	0.00	6.00	0.00	6.00	
320	Boulders/bedrock (crevices)	2	26.00	18.50	0.00	44.50	22.00 ± 6.47
340	Boulders/cobble	2	2.00	2.50	6.50	11.00	
348	Boulders/cobble/shell	2	9.50	4.50	0.00	14.00	
380	Boulders/shell	1	14.00	1.00	0.00	15.00	

Table 26d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the November, 2001 survey (Plumper Islands only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = size unknown, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
000	Unknown	15	1.67	2.53	0.00	4.20	4.20 ± 1.40
100	Bedrock (smooth)	38	0.79	0.84	2.21	3.84	7.09 ± 1.63
120	Bedrock (smooth)/bedrock (crevices)	1	0.00	0.00	49.00	49.00	
130	Bedrock (smooth)/boulders	5	4.40	4.20	8.40	17.00	
140	Bedrock (smooth)/cobble	2	12.50	5.50	5.00	23.00	
200	Bedrock (crevices)	14	0.71	1.43	1.50	3.64	3.64 ± 1.47
300	Boulders	14	2.93	3.21	0.43	6.57	6.05 ± 1.14
340	Boulders/cobble	1	5.00	8.00	0.00	13.00	
360	Boulders/pea gravel	4	0.75	1.75	0.00	2.50	
400	Cobble	10	4.40	6.60	0.10	11.10	11.10 ± 2.40
560	Gravel/pea gravel	2	0.50	3.00	0.00	3.50	3.50 ± 3.50
700	Sand	1	0.00	0.00	0.00	0.00	0.00
800	Shell	1	0.00	6.00	0.00	6.00	3.00 ± 3.00
810	Shell/bedrock (smooth)	1	0.00	0.00	0.00	0.00	

Table 27. Summary results of measurements taken during green urchin dissections from the November, 2001 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. SE = Standard Error; *Gutted Weight = stomach contents removed only; Gonad Texture: 0=unknown or no sample, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or no sample, 1=firm, 2=semi-firm, 3=flimsy; Sex: 1=male, 2=female, 3=juvenile or unknown). Sample Size is for all calculations.

Summary Information			**LOCATION**								
			STEPHENSON ISLETS			**STUBBS ISLAND**			**PLUMPER ISLANDS**		
			Legal	**Sublegal-mature**	**Sublegal-immature**	**Legal**	**Sublegal-mature**	**Sublegal-immature**	**Legal**	**Sublegal-mature**	**Sublegal-immature**
Sample Size			46	41	1	20	16	1	18	24	0
Mean Test Height (mm) ± SE			31.5 (± 0.6)	22.6 (± 0.6)	10.0	34.3 (± 1.2)	22.6 (± 0.9)	10.0	32. 7 (± 0.7)	21.8 (± 0.9)	0
Mean Test Diameter (mm) ± SE			62.0 (± 0.9)	44.7 (± 0.9)	22.0	66.7 (± 1.8)	44.1 (± 1.5)	22.0	64.3 (± 1.5)	44.3 (± 1.6)	0
Mean Total Wet Weight (g) ± SE			85.58 (± 3.93)	34.53 (± 1.95)	4.40	107.24 (± 9.65)	33.77 (± 3.07)	4.50	91.34 (± 5.83)	33.23 (± 2.96)	0
Mean Drained Weight (g) ± SE			64.53 (± 2.75)	28.88 (± 1.59)	4.10	81.31 (± 6.50)	28.31 (± 2.41)	4.50	67.95 (± 4.00)	27.57 (± 2.26)	0
*Mean Gutted Weight (g) ± SE			51.42 (± 2.29)	22.64 (± 1.27)	2.70	67.36 (± 5.05)	21.81 (± 1.84)	3.40	56.21 (± 3.42)	22.19 (± 1.96)	0
*Mean Stomach Content Weight (g) ± SE			13.10 (± 0.71)	6.24 (±0.61)	1.40	13.95 (± 1.72)	6.51 (± 0.67)	1.10	11.74 (± 1.29)	5.38 (± 0.49)	0
Sex	% Male		46	44	0	30	44	0	67	58	0
	% Female		48	39	0	65	44	0	33	29	0
	% Unknown		7	17	0	5	12	0	0	13	0
Gonad	Mean Weight (g) ± SE		10.30 (± 0.77)	4.30 (± 0.43)	0	17.16 (± 1.56)	3.41 (± 0.53)	0	13.59 (± 1.35)	4.35 (± 0.59)	0
	Colour Proportion	0	0	0	1.00	0	0	1.00	0	0	0
		1	0.54	0.83	0	0.55	0.81	0	0.50	0.79	0
		2	0.33	0.15	0	0.35	0.13	0	0.44	0.13	0
		3	0.13	0.02	0	0.10	0.06	0	0.06	0.08	0
	Texture Proportion	0	0	0	1.00	0	0	1.00	0	0	0
		1	0.72	0.61	0	0.65	0.63	0	0.94	0.88	0
		2	0.26	0.34	0	0.25	0.38	0	0.06	0.08	0
		3	0.02	0.05	0	0.10	0	0	0	0.04	0

Table 28. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in November, 2001 (incorporates estimates from unknowns). (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Size Category	**Stephenson Islets**	**Stubbs Island**	**Plumper Islands**
Number of Legal-sized	873,360 ± 191,204	102,558 ± 23,530	615,413 ± 214,809
Number of Sublegal-mature	1,876,107 ± 386,510	79,995 ± 17,724	738,495 ± 142,477
Number of Sublegal-immature	134,964 ± 36,883	2,507 ± 503	38,976 ± 16,423
Number of all sizes	2,884,430 ± 400,732	185,060 ± 32,365	1,392,884 ± 347,912
Biomass of Legal-size (t)	69.55 ± 15.23	9.19 ± 2.11	54.63 ± 19.09
Biomass of Sublegal-mature (t)	61.43 ± 12.66	2.65 ± 0.59	22.26 ± 4.32
Biomass of Sublegal-immature (t)	0.43 ± 0.12	0.01 ± 0.002	0.16 ± 0.07
Total Biomass (t)	131.40 ± 19.81	11.85 ± 2.19	77.05 ± 19.57

Table 29. Means and standard errors (SE) of test diameters (TD) (using October, 2002. field survey data) and weight (using TD-total wet weight relationships from October, 2002 lab measurements, and applying to field survey data) of legal, sublegal-mature and immature green sea urchins from each of the survey sites. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD).

Site	Size	Sample Size	Mean TD (mm)	SE of Mean TD (mm)	Mean Weight (g)	SE of Mean Weight (g)
All Sites Combined	Legal	1213	62.0	0.2	82.8	0.7
	Sublegal-Mature	1631	44.6	0.2	33.9	0.3
	Sublegal-Immature	68	17.3	0.8	2.9	0.3
Stephenson Islets	Legal	611	60.3	0.2	71.8	0.7
	Sublegal-Mature	1217	44.3	0.2	31.8	0.4
	Sublegal-Immature	55	17.5	0.9	2.9	0.3
Stubbs Island	Legal	344	64.7	0.4	98.7	1.7
	Sublegal-Mature	230	44.5	0.5	35.5	0.9
	Sublegal-Immature	7	18.3	1.9	3.1	0.8
Plumper Islands	Legal	258	62.5	0.4	88.5	1.6
	Sublegal-Mature	184	46.2	0.5	38.3	0.9
	Sublegal-Immature	6	14.2	2.4	1.8	0.9

Table 30. Sample mean densities (number/m^2) by transect for green sea urchins of legal size, sublegal size, unknown size, and all sizes (total) in the October, 2002 survey. (Legal = ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD, Unknown = unmeasured, Total Density = density of all urchins combined). Stephenson Islets = Transects 3 to 14, Stubbs Island = Transects 16 to 18, and Plumper Islands = Transects 20 to 23[3].

Transect Number	Number of Quadrats	Legal Density	Sublegal – Mature Density	Sublegal – Immature Density	Unknown Density	Total Density
3	29 M 57 T	1.79 (3.21)	1.70 (3.04)	0.12 (0.23)	2.86 (0.00)	6.47
5A	18 M 37 T	0.89 (2.35)	2.68 (7.08)	0.00	5.86 (0.00)	9.43
6	11 M 23 T	1.26 (2.87)	1.61 (3.65)	0.13 (0.30)	3.83 (0.00)	6.83
7	63 M 73 T	1.41 (1.63)	3.27 (3.77)	0.16 (0.19)	0.74 (0.00)	5.59
8	8 M 15 T	0.87 (1.67)	0.33 (0.60)	0.00	1.07 (0.00)	2.27
9	35 M 71 T	1.28 (2.68)	4.68 (9.77)	0.17 (0.35)	6.68 (0.00)	12.80
10	10 M 21 T	0.43 (0.90)	0.43 (0.86)	0.00	0.90 (0.00)	1.76
11	29 M 58 T	1.93 (4.19)	1.90 (4.12)	0.02 (0.03)	4.50 (0.00)	8.34
13	19 M 37 T	1.76 (4.14)	2.95 (6.95)	0.22 (0.51)	6.68 (0.00)	11.59
14	35 M 59 T	0.37 (0.63)	2.34 (3.88)	0.15 (0.25)	1.90 (0.00)	4.76
Stephenson Islets Totals or Avg.	257 M 451 T	1.28 ± 0.18 (2.49 ± 0.42)	2.61 ± 3.34 (4.97 ± 0.96)	0.12 ± 0.02 (0.21 ± 0.05)	3.66 ± 0.84 (0.00)	7.67 ± 1.14
16	16	7.50	2.56	0.13	0.00	10.19
17	30	4.07	4.70	0.10	0.00	8.87
18	20	3.95	1.40	0.10	0.00	5.45
Stubbs Island Totals or Avg.	66 T	4.86 ± 0.96	3.18 ± 1.09	0.11 ± 0.01	0.00	8.15 ± 1.24
20	33	2.18	2.06	0.00	0.00	4.24
21	14 M 27 T	0.56 (1.00)	0.41 (0.70)	0.00	0.74 (0.00)	1.70
22	31	4.81	2.00	0.06 (0.06)	0.00	6.87
23	15	0.00	0.20	0.20	0.00	0.40
Plumper Islands Totals or Avg.	93 M 106 T	2.23 ± 1.07 (2.34 ± 1.00)	1.36 ± 0.47 (1.43 ± 0.42)	0.05 ± 0.03 (0.05 ± 0.03)	0.19 ± 0.19 (0.00)	3.82 ± 1.34
OVERALL TOTAL	416 M 623 T	1.82 ± 0.32 (2.71 ± 0.37)	2.45 ± 0.35 (4.18 ± 0.78)	0.10 ± 0.02 (0.17 ± 0.04)	2.68 ± 0.71 (0.00)	7.06 ± 0.91

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[3] The numbers in the brackets indicate calculations where the unknowns have been proportioned into legal and sublegal values using the ratios from measured data, then added to the original legal and sublegal values, and assigning a zero value to the unknowns. M=measured quadrats; T=total quadrats (measured and counted).

Table 31a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD from all survey sites combined in the October, 2002 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-7 to -5	-2.1 to -1.5	6	0.00	0.00	0.00
-4 to 0	-1.2 to 0.0	50	3.32	3.84	7.16 ± 1.06
1 to 5	0.3 to 1.5	87	6.49	7.32	13.82 ± 1.63
6 to 10	1.8 to 3.0	116	3.73	4.34	8.07 ± 1.05
11 to 15	3.3 to 4.8	91	2.76	3.88	6.64 ± 0.78
16 to 20	4.9 to 6.1	106	2.33	3.34	5.67 ± 0.49
21 to 25	6.4 to 7.6	92	1.67	3.59	5.26 ± 0.61
26 to 30	7.9 to 9.1	75	1.04	3.53	4.57 ± 0.84
31 to 35	9.4 to 10.7	49	0.73	1.55	2.29 ± 0.39
36	11.0	1	0.00	0.00	0.00

Table 31b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Stephenson Islets in the October, 2002 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-5	-1.5	5	0.00	0.00	0.00
-4 to 0	-1.2 to 0.0	30	2.63	3.43	6.07 ± 1.33
1 to 5	0.3 to 1.5	58	5.76	9.78	15.53 ± 2.26
6 to 10	1.8 to 3.0	92	2.74	4.61	7.35 ± 0.84
11 to 15	3.3 to 4.8	65	2.77	5.06	7.83 ± 1.00
16 to 20	4.9 to 6.1	81	2.31	4.35	6.65 ± 0.54
21 to 25	6.4 to 7.6	69	1.35	4.64	5.99 ± 0.72
26 to 30	7.9 to 9.1	51	1.00	4.84	5.84 ± 1.17
31 to 35	9.4 to 10.7	33	0.21	1.85	2.06 ± 0.41
36	11.0	1	0.00	0.00	0.00

Table 31c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD at Stubbs Island in the October, 2002 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. No unmeasured urchins).

Depth Range (ft)	Depth Range (m)	Number Of Quadrats	Legal Density	Sublegal Density	Total Density
-7 to -5	-2.1 to -1.5	1	0.00	0.00	0.00
-4 to 0	-1.2 to 0.0	13	3.92	3.31	7.23 ± 2.09
1 to 5	0.3 to 1.5	13	11.08	7.00	18.08 ± 1.68
6 to 10	1.8 to 3.0	13	7.38	4.46	11.85 ± 1.65
11 to 15	3.3 to 4.8	12	3.25	2.58	5.83 ± 1.58
16 to 20	4.9 to 6.1	6	1.50	0.67	2.17 ± 1.80
21 to 25	6.4 to 7.6	7	0.71	0.57	1.29 ± 0.97
26 to 30	7.9 to 9.1	5	0.00	0.80	0.80 ± 0.49
31 to 35	9.4 to 10.7	5	0.00	0.40	0.40 ± 0.40

Table 31d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by depth range (feet and meters) below CD in the Plumper Islands in the October, 2002 survey. (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD. The unmeasured urchins have been proportioned into the legal and sublegal estimated values using the proportions of legal and sublegal urchins in the measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns).

Depth Range (ft)	Depth Range (m)	Number of Quadrats	Legal Density	Sublegal Density	Total Density
-3 to 0	-0.9 to 0.0	7	4.71	7.00	11.71 ± 2.87
1 to 5	0.3 to 1.5	16	2.38	1.75	4.13 ± 1.75
6 to 10	1.8 to 3.0	11	5.18	4.45	9.64 ± 8.56
11 to 15	3.3 to 4.8	14	1.14	0.64	1.79 ± 0.61
16 to 20	4.9 to 6.1	19	2.00	0.58	2.58 ± 0.92
21 to 25	6.4 to 7.6	16	2.69	1.19	3.88 ± 1.37
26 to 30	7.9 to 9.1	19	1.16	1.00	2.16 ± 0.69
31 to 35	9.4 to 10.7	11	2.55	1.27	3.82 ± 1.11

Table 32a. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the October, 2002 survey (all areas combined). (Legal ≥ 55 mm TD, Sublegal < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
000	Unknown	1	3.00	1.00	0.00	4.00	4.00 ± 0.00
100	Bedrock (smooth)	182	1.47	2.59	3.40	7.47	6.97 ± 0.50
120	Bedrock (smooth)/bedrock (crevices)	6	1.33	0.50	9.00	10.83	
128	Bedrock (smooth)/bedrock (crevices)/shell	1	0.00	0.00	0.00	0.00	
130	Bedrock (smooth)/boulders	3	0.00	0.67	3.33	4.00	
140	Bedrock (smooth)/cobble	3	0.00	1.33	1.00	2.33	
148	Bedrock (smooth)/cobble/shell	6	0.00	0.50	0.00	0.50	
170	Bedrock (smooth)/sand	4	0.00	2.25	0.50	2.75	
180	Bedrock (smooth)/shell	10	1.40	2.20	0.60	4.20	
200	Bedrock (crevices)	197	1.90	2.92	3.23	8.06	7.73 ± 0.65
210	Bedrock (crevices)/bedrock (smooth)	4	0.75	1.00	1.00	2.75	
230	Bedrock (crevices)/boulders	8	0.38	0.63	3.38	4.38	
234	Bedrock (crevices)/boulders/cobble	1	0.00	0.00	5.00	5.00	
238	Bedrock (crevices)/boulders/shell	7	3.14	1.00	0.00	4.14	
240	Bedrock (crevices)/cobble	22	1.00	4.82	4.91	10.73	
248	Bedrock (crevices)/cobble/shell	13	1.31	1.85	5.85	9.00	
250	Bedrock (crevices)/gravel	3	1.00	4.33	2.00	7.33	
280	Bedrock (crevices)/shell	11	0.27	0.91	0.00	1.18	
300	Boulders	28	3.71	1.50	0.29	5.50	6.37 ± 1.11
318	Boulders/bedrock (smooth)/shell	1	0.00	2.00	0.00	2.00	
328	Boulders/bedrock (crevices)/shell	5	10.00	1.00	0.00	11.00	
340	Boulders/cobble	30	1.00	0.97	1.50	3.47	
345	Boulders/cobble/gravel	1	24.00	12.00	0.00	36.00	
348	Boulders/cobble/shell	27	2.81	2.52	0.59	5.93	
350	Boulders/gravel	2	3.50	2.50	2.50	8.50	
358	Boulders/gravel/shell	2	1.50	3.00	0.00	4.50	
380	Boulders/shell	6	9.33	9.50	0.00	18.83	
400	Cobble	3	1.67	2.00	0.00	3.67	8.89 ± 5.19
420	Cobble/bedrock (crevices)	1	12.00	38.00	0.00	50.00	
430	Cobble/boulders	4	0.50	2.50	0.75	3.75	
450	Cobble/gravel	1	4.00	0.00	0.00	4.00	

Table 32a. (continued)

500	Gravel	25	0.32	1.56	0.88	2.76	3.86 ± 0.99
534	Gravel/boulders/cobble	1	0.00	0.00	2.00	2.00	
580	Cobble/shell	1	1.00	0.00	0.00	1.00	
583	Cobble/shell/boulders	2	6.50	6.50	7.00	20.00	
820	Shell/bedrock (crevices)	1	0.00	0.00	0.00	0.00	0.00

Table 32b. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the October, 2002 survey (Stephenson Islets only). (Legal = $\geq$ 55 mm TD, Sublegal = $<$ 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
000	Unknown	1	3.00	1.00	0.00	4.00	4.00 ± 0.00
100	Bedrock (smooth)	145	1.04	2.32	4.27	7.63	7.45 ± 0.59
120	Bedrock (smooth)/bedrock (crevices)	6	1.33	0.50	9.00	10.83	
130	Bedrock (smooth)/boulders	3	0.00	0.67	3.33	4.00	
140	Bedrock (smooth)/cobble	3	0.00	1.33	1.00	2.33	
148	Bedrock (smooth)/cobble/ Shell	1	0.00	2.00	0.00	2.00	
170	Bedrock (smooth)/sand	4	0.00	2.25	0.50	2.75	
180	Bedrock (smooth)/shell	2	2.00	4.50	3.00	9.50	
200	Bedrock (crevices)	175	1.73	3.05	3.63	8.41	8.45 ± 0.74
210	Bedrock (crevices)/bedrock (smooth)	4	0.75	1.00	1.00	2.75	
230	Bedrock (crevices)/boulders	5	0.60	0.60	5.40	6.60	
234	Bedrock (crevices)/boulders/ cobble	1	0.00	0.00	5.00	5.00	
238	Bedrock (crevices)/boulders/ Shell	2	1.50	1.00	0.00	2.50	
240	Bedrock (crevices)/cobble	19	1.16	5.58	5.68	12.42	
248	Bedrock (crevices)/cobble/ Shell	6	0.00	2.50	12.67	15.17	
250	Bedrock (crevices)/gravel	3	1.00	4.33	2.00	7.33	
280	Bedrock (crevices)/shell	8	0.25	1.00	0.00	1.25	
300	Boulders	5	1.80	1.00	1.60	4.40	6.28 ± 1.39
340	Boulders/cobble	5	1.20	2.80	5.00	9.00	
348	Boulders/cobble/shell	12	0.58	3.42	1.33	5.33	
350	Boulders/gravel	2	3.50	2.50	2.50	8.50	
358	Boulders/gravel/shell	1	3.00	6.00	0.00	9.00	
400	Cobble	3	1.67	2.00	0.00	3.67	9.63 ± 5.82
420	Cobble/bedrock (crevices)	1	12.00	38.00	0.00	50.00	
430	Cobble/boulders	3	0.00	3.00	1.00	4.00	
450	Cobble/gravel	1	4.00	0.00	0.00	4.00	
500	Gravel	25	0.32	1.56	0.88	2.76	3.86 ± 0.99
534	Gravel/boulders/cobble	1	0.00	0.00	2.00	2.00	
580	Gravel/shell	1	1.00	0.00	0.00	1.00	
583	Gravel/shell/boulders	2	6.50	6.50	7.00	20.00	
820	Shell/bedrock (crevices)	1	0.00	0.00	0.00	0.00	0.00

Table 32c. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, and all sizes (total) by substrate type in the October, 2002 survey (Stubbs Island only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Total Density by Main Substrate = density for all urchins within the dominant substrate type. No unmeasured urchins).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	31	3.74	4.35	8.10	8.06 ± 1.12
148	Bedrock (smooth)/cobble/shell	1	0.00	0.00	0.00	
180	Bedrock (smooth)/shell	1	6.00	9.00	15.00	
200	Bedrock (crevices)	3	5.67	3.00	8.67	5.06 ± 2.03
230	Bedrock (crevices)/boulders	3	0.00	0.67	0.67	
238	Bedrock (crevices)/boulders/shell	2	9.50	2.50	12.00	
240	Bedrock (crevices)/cobble	1	0.00	0.00	0.00	
248	Bedrock (crevices)/cobble/shell	5	3.40	1.80	5.20	
280	Bedrock (crevices)/shell	2	0.50	1.00	1.50	
318	Boulders/bedrock (smooth)/shell	1	0.00	2.00	2.00	11.24 ± 2.51
328	Boulders/bedrock (crevices)/shell	5	10.00	1.00	11.00	
340	Boulders/cobble	1	13.00	5.00	18.00	
345	Boulders/cobble/gravel	1	24.00	12.00	36.00	
348	Boulders/cobble/shell	9	6.44	2.44	8.89	

Table 32d. Sample mean densities (urchins/m^2) of green sea urchins of legal size, sublegal size, unknown size and all sizes (total) by substrate type in the October, 2002 survey (Plumper Islands only). (Legal = ≥ 55 mm TD, Sublegal = < 55 mm TD, Unknown = unmeasured, Total Density by Main Substrate = density for all urchins within the dominant substrate type).

Code	Substrate Type	Number of Quadrats	Legal Density	Sublegal Density	Unknown Density	Total Density	Total Density By Main Substrate
100	Bedrock (smooth)	54	0.59	0.91	0.02	1.52	0.61 ± 0.39
128	Bedrock (smooth)/bedrock (smooth)/shell	2	2.00	1.50	0.00	3.50	
148	Bedrock (smooth)/cobble/shell	3	1.33	6.00	0.00	7.33	
180	Bedrock (smooth)/shell	9	0.00	1.00	0.00	1.00	
200	Bedrock (crevices)	15	3.73	1.27	0.00	5.00	3.30 ± 1.19
238	Bedrock (crevices)/boulders/ Shell	2	1.00	0.50	0.00	1.50	
240	Bedrock (crevices)/cobble	1	1.00	6.00	0.00	7.00	
248	Bedrock (crevices)/cobble/ Shell	2	0.00	0.00	0.00	0.00	
280	Bedrock (crevices)/shell	7	1.71	1.86	0.00	3.57	
300	Boulders	18	0.50	1.39	0.00	1.89	5.03 ± 1.62
340	Boulders/cobble	7	0.00	0.57	0.00	0.57	
348	Boulders/cobble/shell	1	0.00	0.00	0.00	0.00	
358	Boulders/gravel/shell	5	0.00	2.00	0.00	2.00	
380	Boulders/shell	1	0.00	0.00	0.00	0.00	
430	Gravel/boulders	6	0.00	2.67	0.00	2.67	3.00 ± 0.00

Table 33. Summary results of measurements taken during green urchin dissections from the October, 2002 survey. (Legal ≥ 55 mm TD, Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. SE = Standard Error; Gutted Weight = stomach and contents removed; Gonad Texture: 0=unknown or no sample, 1=orange/yellow, 2=yellow with other colours, 3=brown/red; Gonad Texture: 0=unknown or no sample, 1=firm, 2=semi-firm, 3=flimsy; Sex: 1=male, 2=female, 3=juvenile or unknown). Sample Size 1 is for test height, TD and total wet weight and Sample Size 2 is for all other calculations.

Summary Information			**LOCATION**								
			STEPHENSON ISLETS			**STUBBS ISLAND**			**PLUMPER ISLANDS**		
			Legal	**Sublegal-mature**	**Sublegal–immature**	**Legal**	**Sublegal–mature**	**Sublegal–immature**	**Legal**	**Sublegal-mature**	**Sublegal–immature**
Sample Size 1			**90**	**113**	**6**	**30**	**27**	**1**	**32**	**21**	**0**
Mean Test Height (mm) ± SE			31.9 (± 0.4)	22.5 (± 0.4)	9.0 (±1.4)	34.6 (± 0.7)	22.4 (± 0.9)	9.0	32.7 (± 0.6)	22.8 (± 0.8)	0
Mean Test Diameter (mm) ± SE			61.2 (± 0.5)	44.1 (± 0.8)	17.0 (± 2.6)	68.6 (± 1.3)	44.4 (± 1.3)	19.0	64.3 (± 1.1)	46.0 (± 1.3)	0
Mean Total Wet Weight (g) ± SE			81.34 (± 2.17)	33.43 (± 1.42)	3.25 (± 1.15)	117.91 (± 6.32)	34.91 (± 2.69)	2.70	93.27 (± 4.26)	36.64 (± 3.09)	0
Sample Size 2			**40**	**45**	**3**	**14**	**13**	**0**	**15**	**9**	**0**
Mean Drained Weight (g) ± SE			64.16 (± 3.03)	26.26 (± 1.72)	5.43 (± 0.79)	87.61 (± 6.99)	32.52 (± 4.06)	0	79.33 (± 4.12)	28.28 (± 4.25)	0
Mean Gutted Weight (g) ± SE			45.95 (± 2.32)	18.60 (± 1.29)	3.57 (± 0.52)	61.97 (± 5.14)	23.99 (± 3.21)	0	53.47 (± 3.00)	20.07 (± 3.26)	0
Mean Stomach and Content Weight (g) ± SE			18.22 (±1.20)	7.66 (± 0.50)	1.87 (± 0.30)	25.64 (± 2.07)	8.53 (± 0.88)	0	25.87 (±1.83)	8.21 (± 1.14)	0
Sex	% Male		43	31	0	36	39	0	27	33	0
	% Female		52	62	33	64	46	0	73	67	0
	% Unknown		5	7	67	0	15	0	0	0	0
Gonad	Mean Weight (g) ± SE		11.46 (± 1.14)	3.26 (± 0.42)	0.17 (± 0.09)	15.06 (± 1.92)	5.56 (± 1.05	0	13.84 (± 0.99)	4.44 (± 1.12)	0
	Colour Proportion	0	0	0.02	0.33	0	0.08	0	0	0	0
		1	0.80	0.91	0.67	0.71	0.92	0	0.93	0.89	0
		2	0.15	0.04	0	0.29	0	0	0.07	0.11	0
		3	0.05	0.02	0	0	0	0	0	0	0
	Texture Proportion	0	0	0.02	0.33	0	0.08	0	0	0	0
		1	0.93	0.67	0.33	0.86	0.38	0	0.93	0.44	0
		2	0.08	0.31	0.33	0.14	0.46	0	0.07	0.56	0
		3	0	0	0	0	0.08	0	0	0	0

Table 34. Calculated total abundance (number) and biomass (tonnes) of green sea urchins by site and size category in October, 2002 (incorporates estimates from unknowns). (Legal ≥ 55 mm test diameter (TD), Sublegal-mature 25 mm ≥ TD < 55 mm, Sublegal-immature < 25 mm TD. Biomass estimates were calculated using TD-weight relationships determined from October, 2002 lab measurements for each of the three sites separately, and applied to the field survey TD measurements).

Size Category	Stephenson Islets	Stubbs Island	Plumper Islands
Number of Legal-sized	1,207,083 ± 204,958	95,327 ± 18,846	523,140 ± 223,440
Number of Sublegal-mature	2,409,863 ± 463,376	62,364 ± 21,340	320,634 ± 93,290
Number of Sublegal-immature	102,204 ± 23,660	2,079 ± 136	10,547 ± 7,543
Number of all sizes	3,719,149 ± 554,667	159,770 ± 24,237	854,321 ± 276,504
Biomass of Legal-size (t)	86.72 ± 14.73	9.41 ± 1.86	46.27 ± 19.78
Biomass of Sublegal-mature (t)	76.65 ± 14.75	2.21 ± 0.76	12.26 ± 3.58
Biomass of Sublegal-immature (t)	0.29 ± 0.07	0.01 ± 0.001	0.02 ± 0.02
Total Biomass (t)	163.65 ± 20.85	11.63 ± 2.01	58.55 ± 20.10

Table 35. Fishing seasons for Area 12 and harvest details for the Stephenson Islets.

Fishing Season	Fishing Period for the Season	Area 12 Closing Date	Harvest Weight (t) from Stephenson Islets	Stephenson Islets % of Area 12 Total Harvest	Exploitation at Stephenson Islets
1998/1999	Nov. 10, 1998 - Mar. 15, 1999	Jan. 13, 1999	10.15	13.25	0.13 ± 0.04
1999/2000	Nov. 10, 1999 - Mar. 15, 2000	Jan. 19, 2000	13.39	12.69	0.17 ± 0.04
2000/2001	Nov. 10, 2000 - Mar. 15, 2001	Mar. 15, 2001	12.17	11.66	0.29 ± 0.03
2001/2002	Nov. 20, 2001 - Apr. 19, 2002	Apr. 19, 2002	11.30	18.23	0.16 ± 0.01
2002/2003	Nov. 4, 2002 - Mar. 15, 2003	Mar. 15, 2003	6.69	8.53	0.08 ± 0.002

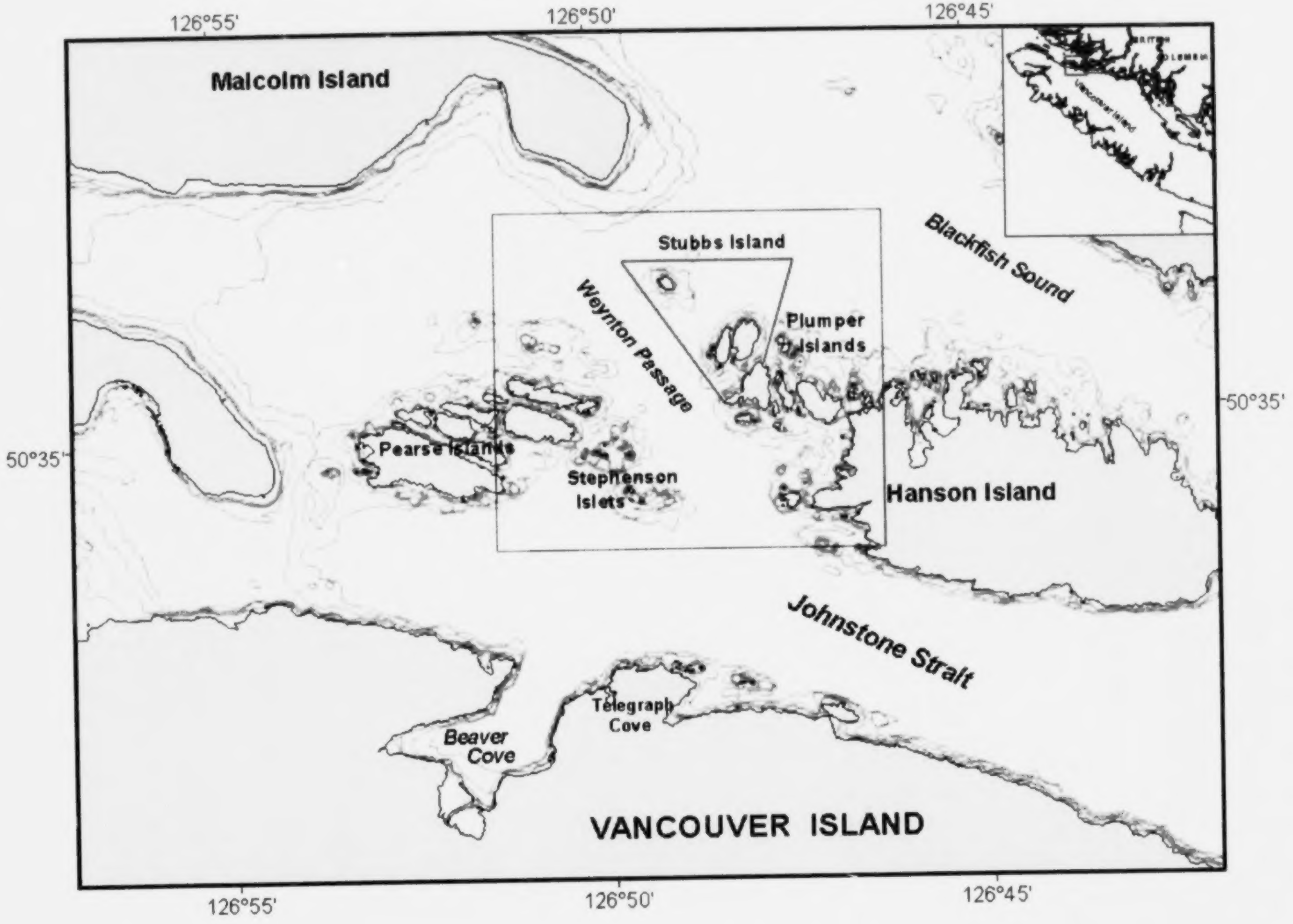

126°55'
126°50'
126°45'
Malcolm Island
Stubbs Island
Blackfish Sound
Plumper Islands
Weynton Passage
50°35'
Pearse Islands
Stephenson Islets
Hanson Island
Johnstone Strait
Telegraph Cove
Beaver Cove
VANCOUVER ISLAND

Fig. 1a. Site locations for the November, 1998, 1999, 2000, 2001 and October, 2002 green urchin surveys (Stephenson Islets, Stubbs Island and the Plumper Islands. The red border represents the boundaries of the research closure area. No commercial fishing may occur within these boundaries.

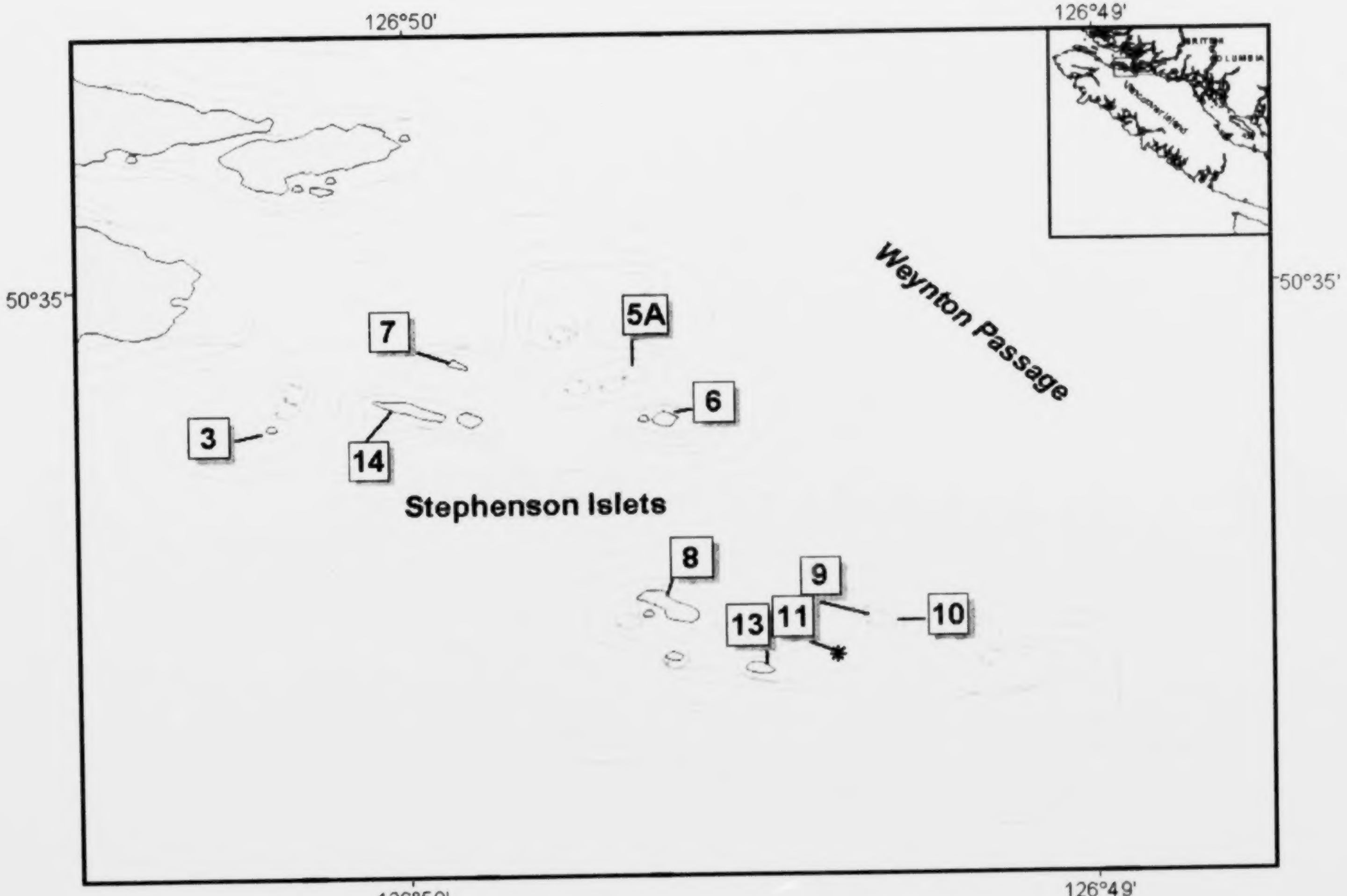

126°50'
126°49'
50°35'
50°35'
Weynton Passage
Stephenson Islets
3
7
14
5A
6
8
9
11
13
10
126°50'
126°49'

Fig. 1b. Transect locations (black lines) for the November, 1998, 1999, 2000, 2001 and October, 2002 green sea urchin surveys, Stephenson Islets.

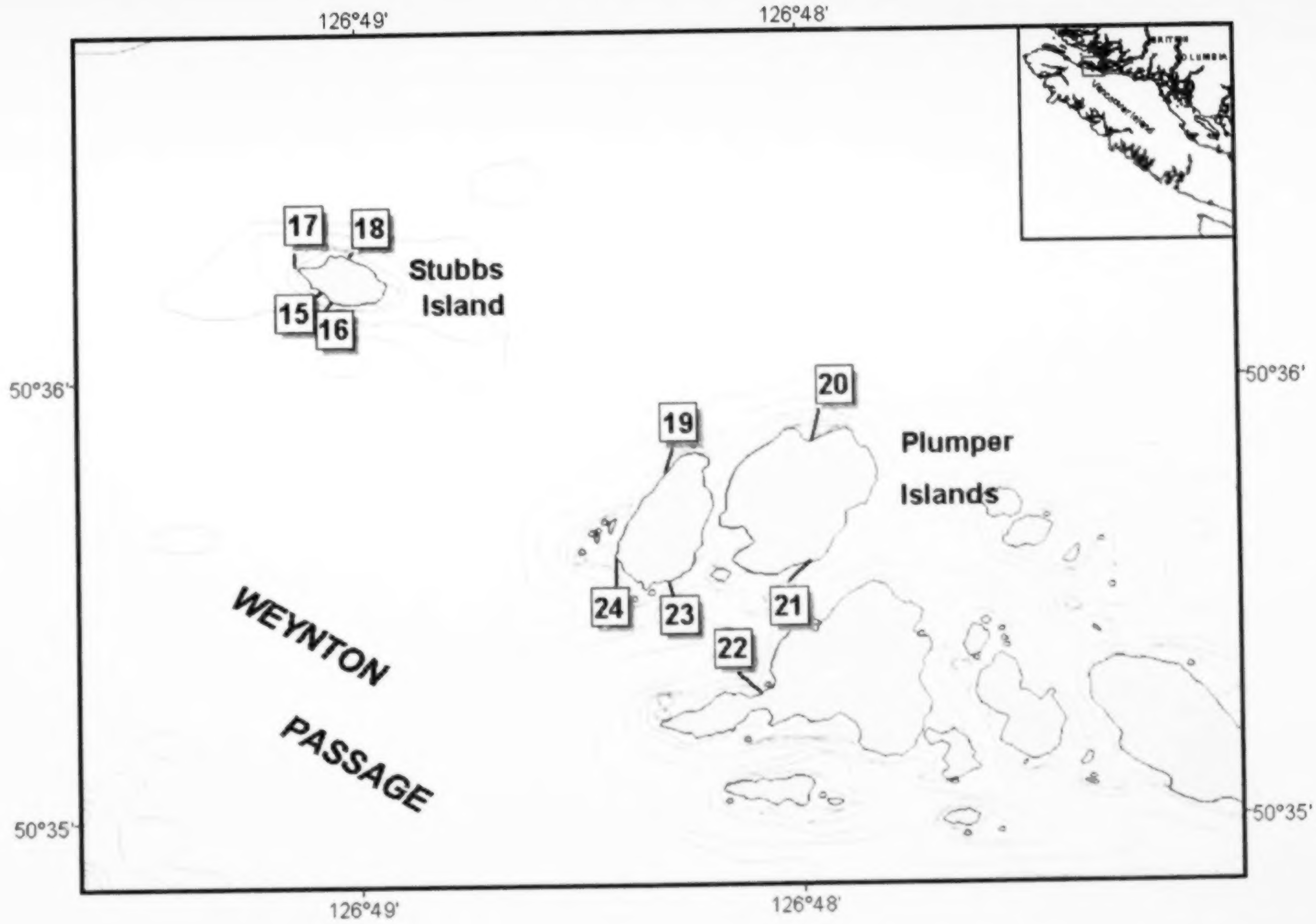

126°49'
126°48'
50°36'
50°35'
17
18
Stubbs
Island
15
16
20
19
Plumper
Islands
24
23
21
22
WEYNTON
PASSAGE

Fig. 1c. Transect locations (black lines) for the November, 1998, 1999, 2000, 2001 and October, 2002 green sea urchin surveys, Stubbs Island and the Plumper Islands.

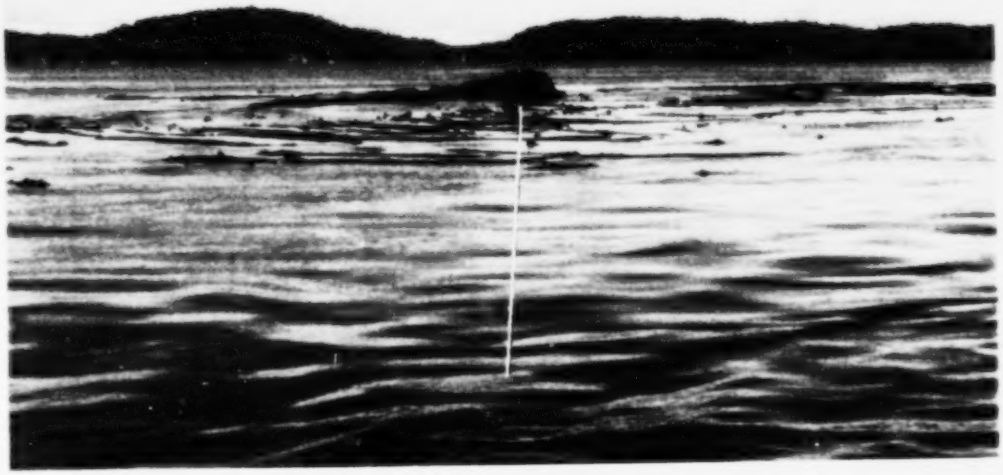


Fig. 2a. Photo of Transect 9 (white line) the Stephenson Islets, looking from the north-west end towards the southeast. Transect 10 is located on the other side of the rock.

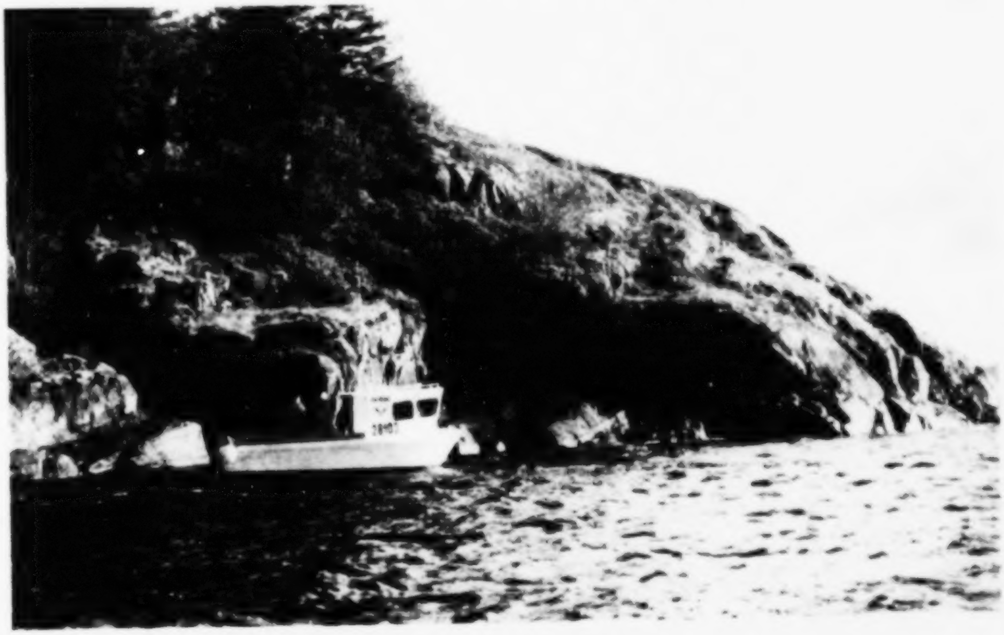
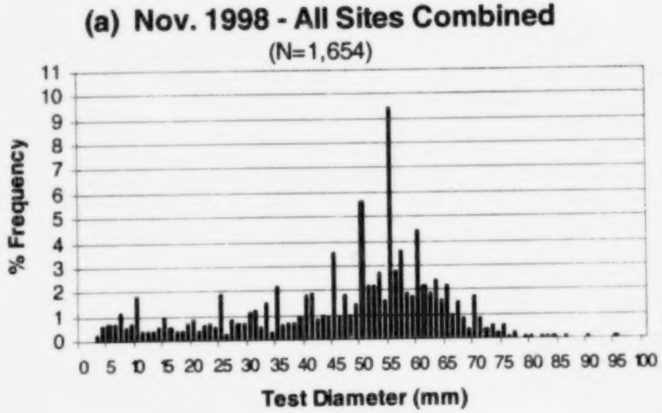
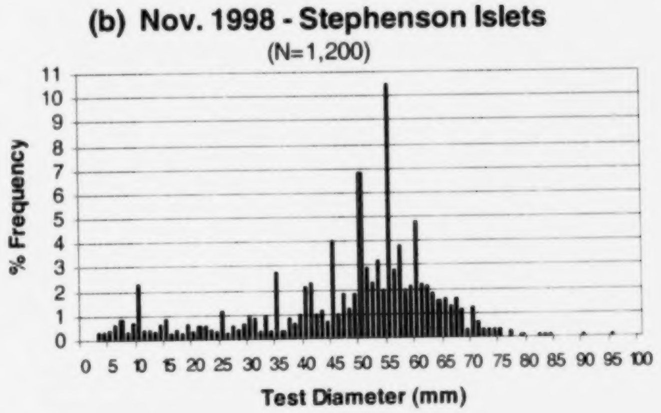
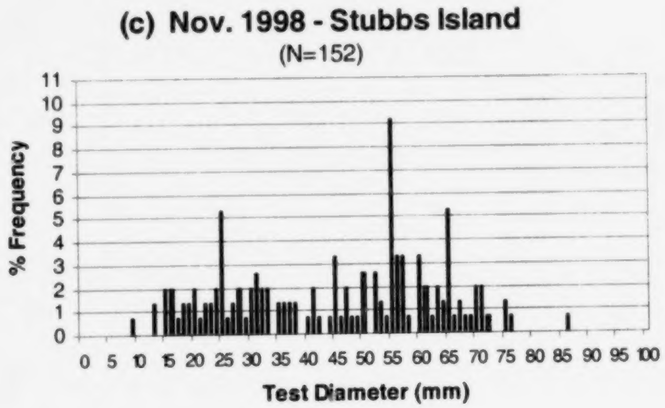


Fig. 2(b). Photo of Transect 15 at Stubbs Island. The transect is in the crevice, to the right of the bow of the boat.


(a) Nov. 1998 - All Sites Combined
(N=1,654)


(b) Nov. 1998 - Stephenson Islets
(N=1,200)


(c) Nov. 1998 - Stubbs Island
(N=152)

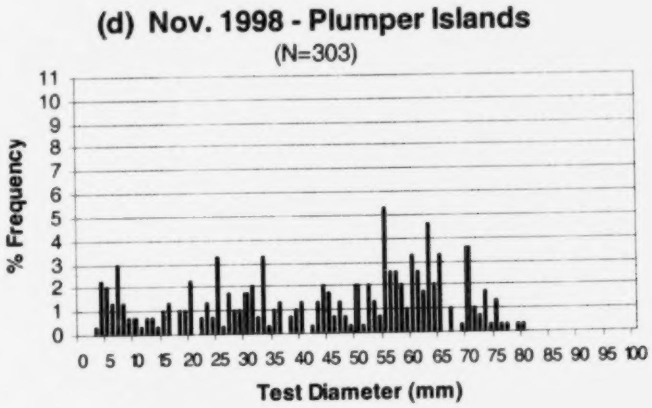

(d) Nov. 1998 - Plumper Islands
(N=303)

Fig. 3. Size (test diameter in millimeters) distributions of green sea urchins collected in November, 1998 from (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

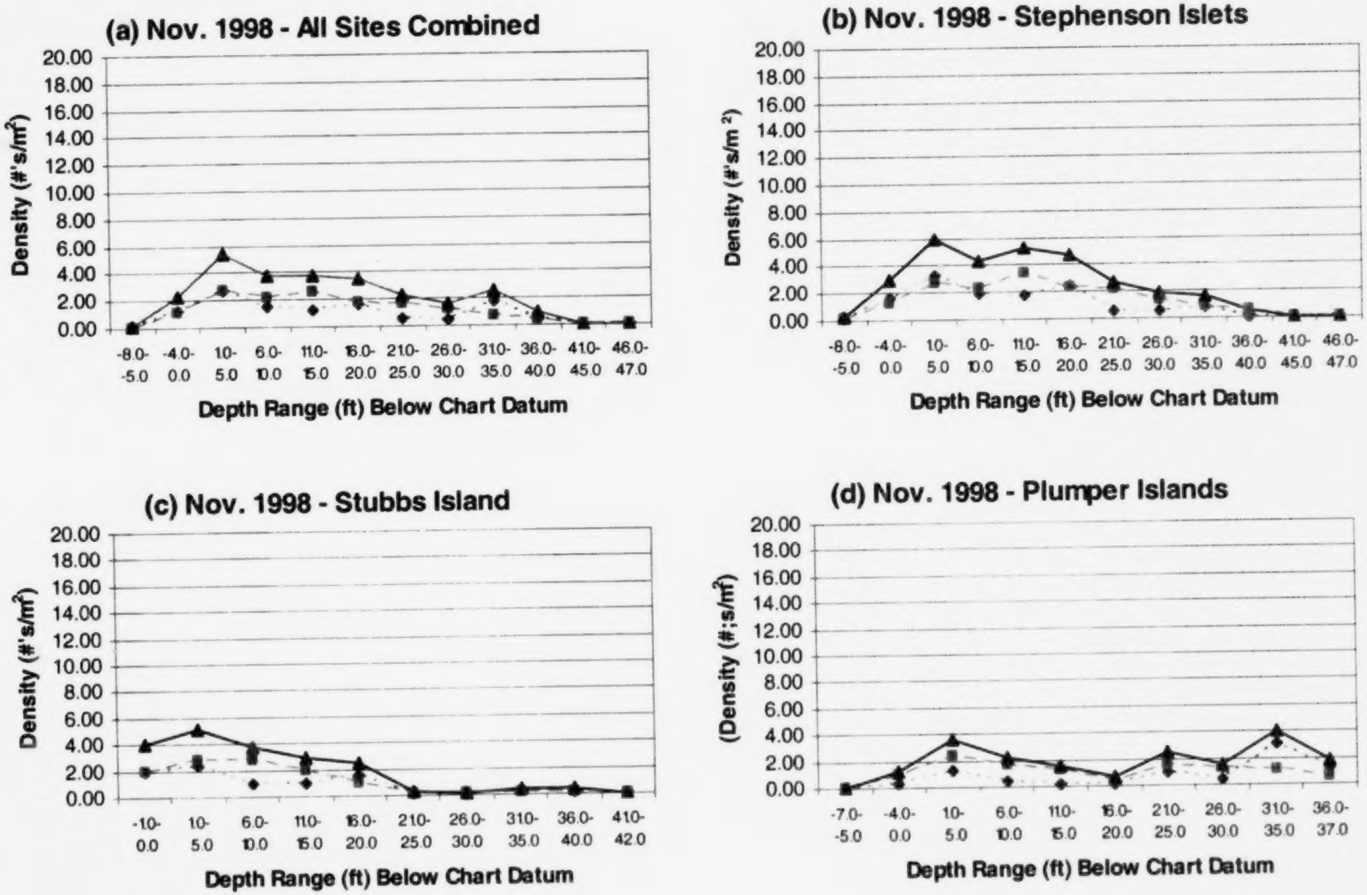
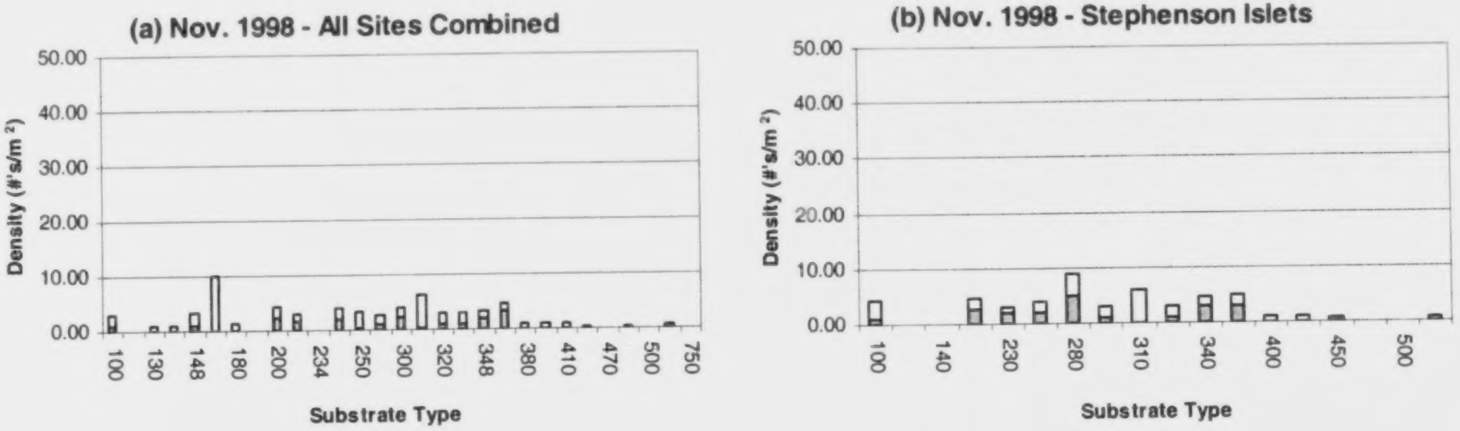


Fig. 4. November, 1998 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the density scale is consistent for all of the "density by depth" charts between all five surveys.



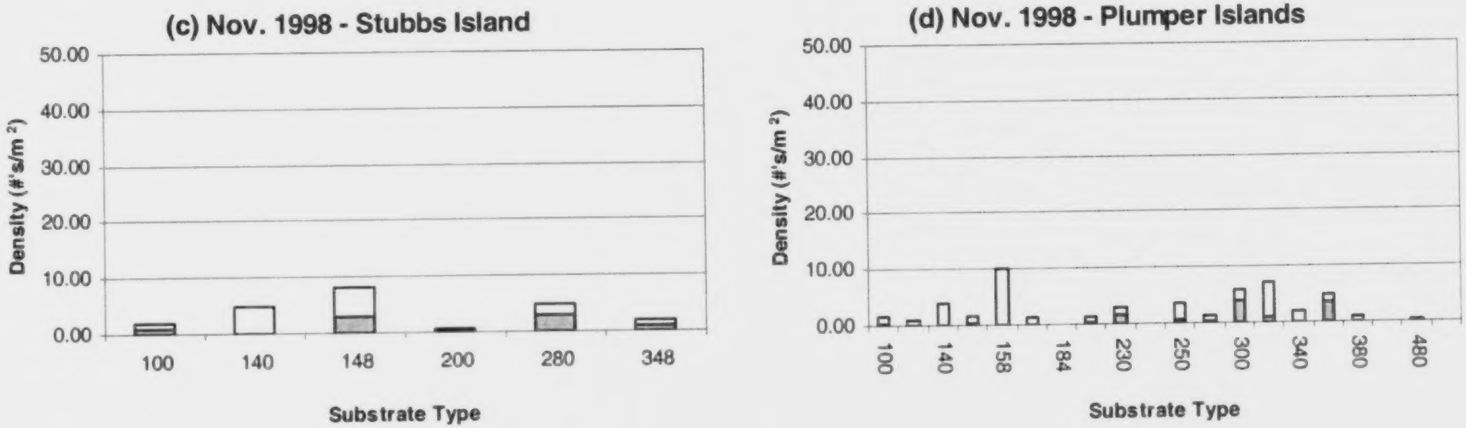


Fig. 5. November, 1998 mean densities (number per square meter) of green sea urchins of legal size (grey) and sublegal (white), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 8a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between all five surveys throughout the report.

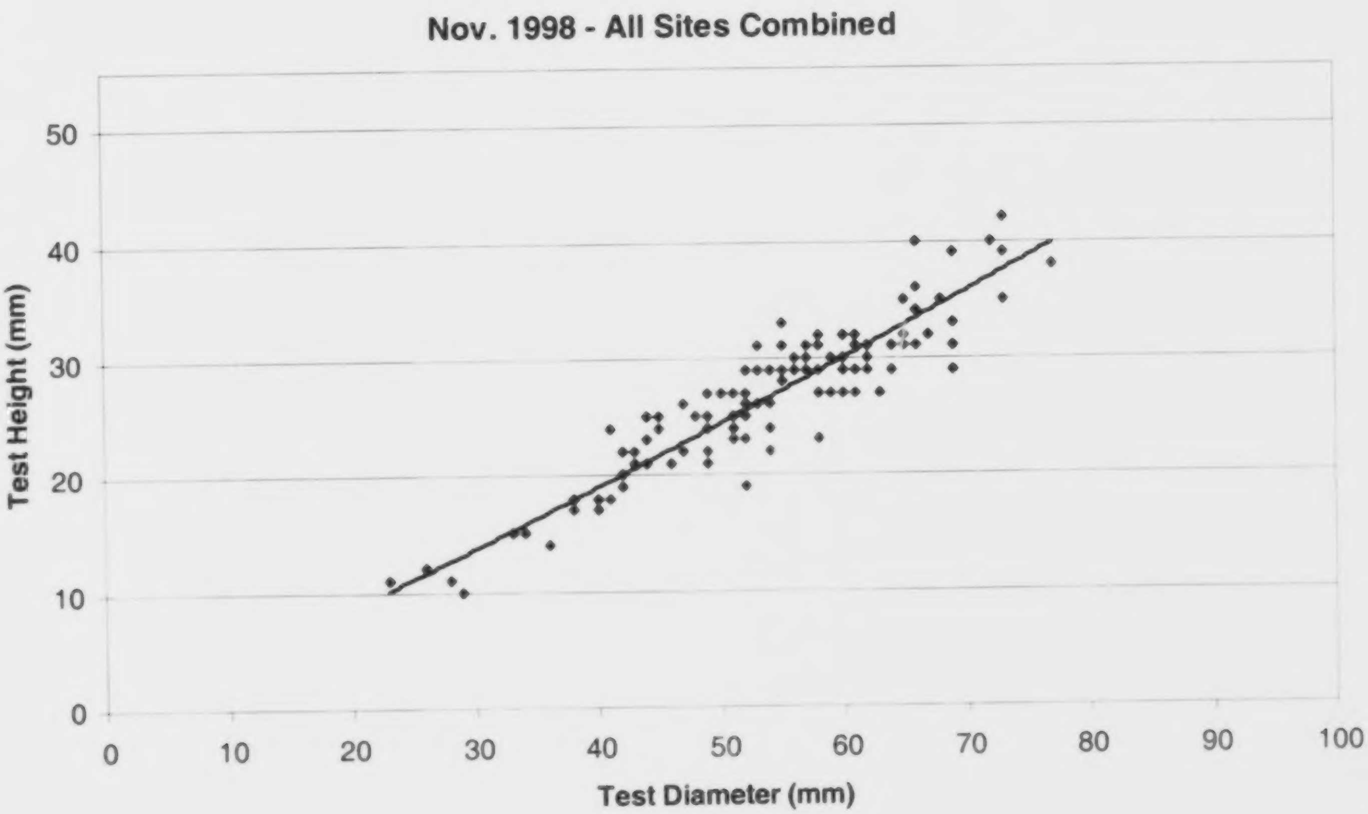
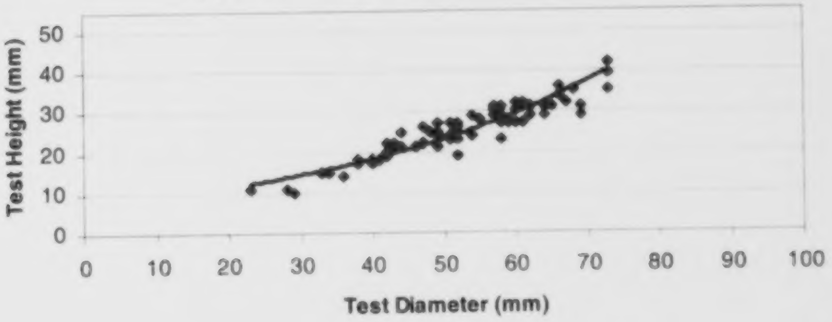
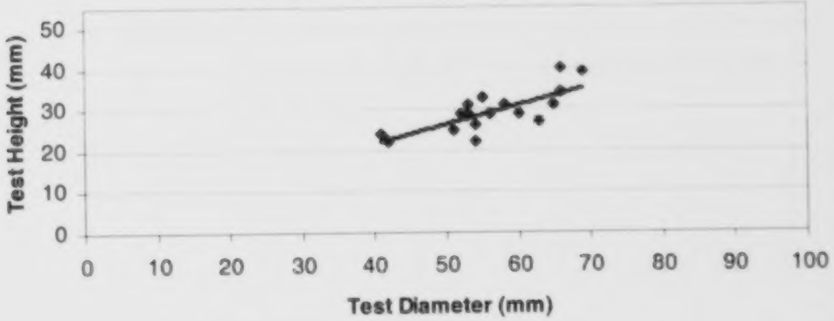


Fig. 6. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 1998, for all sites combined: TEST HEIGHT (mm) = 0.2904($TD^{1.1329}$), $R^2 = 0.8792$, n=128.

(a) Nov. 1998 - Stephenson Islets



(b) Nov. 1998 - Stubbs Island



(c) Nov. 1998 - Plumper Islands

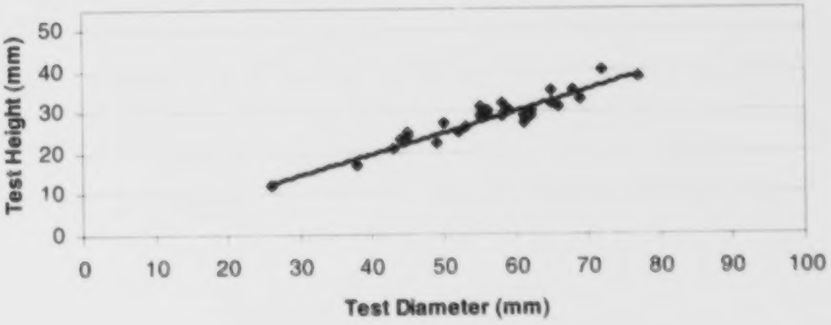


Fig. 7. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 1998 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.2609(\mathrm{TD}^{1.1567})$, $R^2 = 0.8962$, n=81);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.8086(\mathrm{TD}^{0.8906})$, $R^2 = 0.5734$, n=17);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.4090(\mathrm{TD}^{1.0497})$, $R^2 = 0.9144$, n=30).

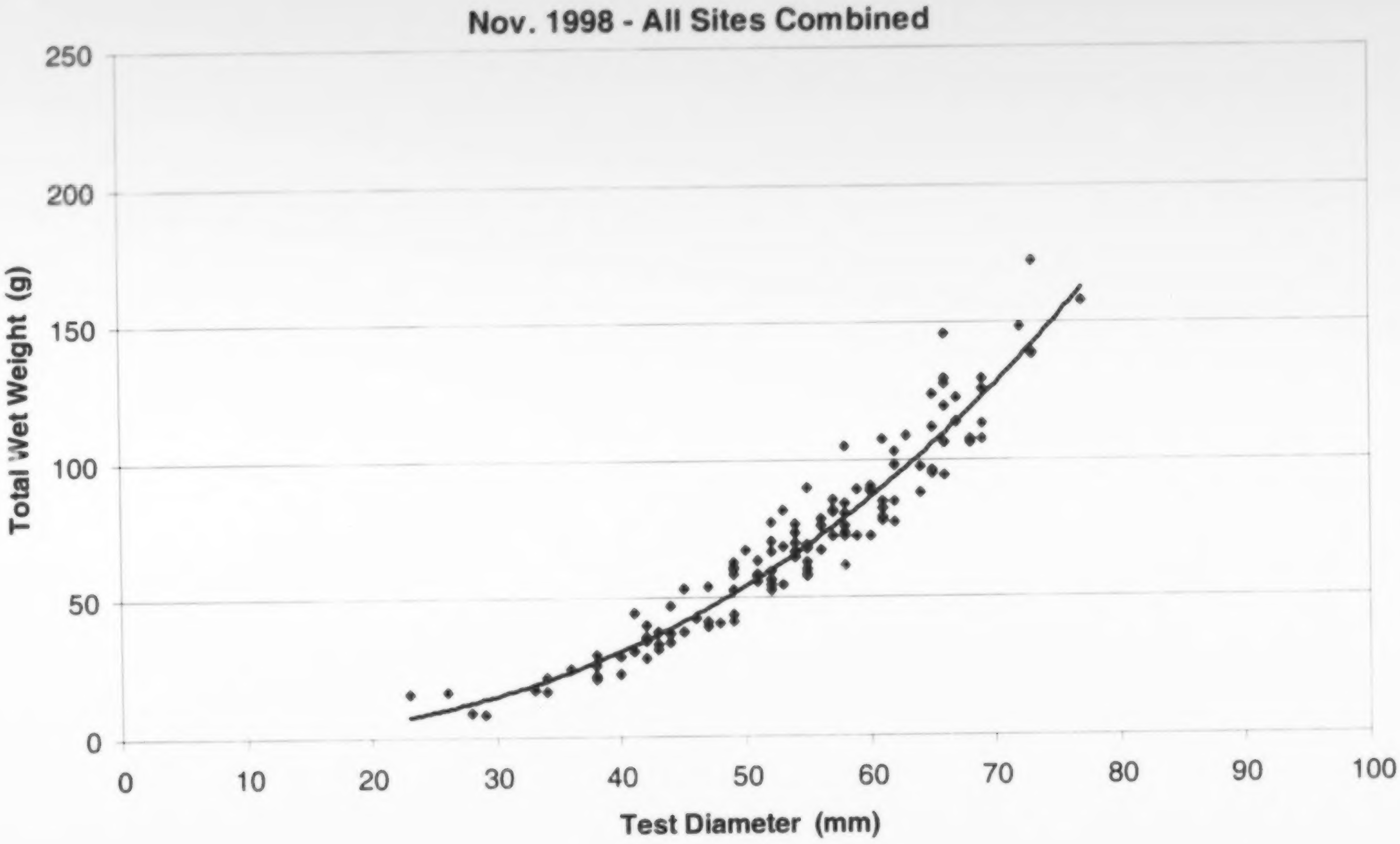
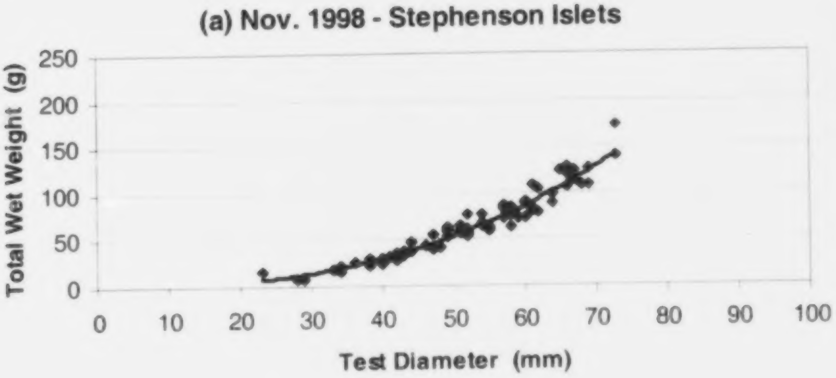
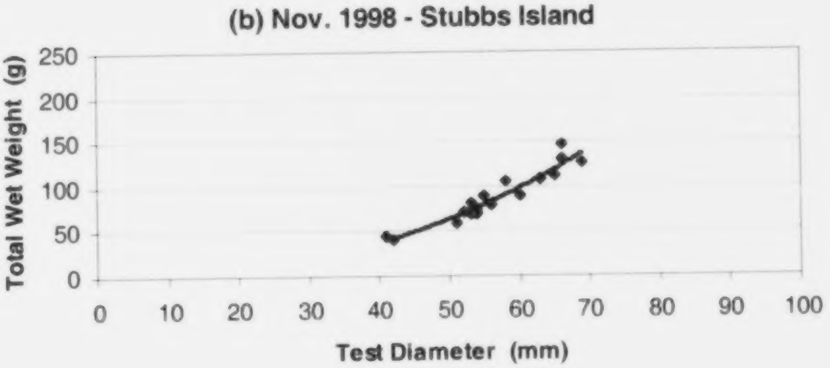


Fig. 8. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 1998, for all sites combined: TOTAL WET WEIGHT (g) = $0.0026(\mathrm{TD}^{2.5423})$, $R^2 = 0.9245$, n=128.


(a) Nov. 1998 - Stephenson Islets


(b) Nov. 1998 - Stubbs Island

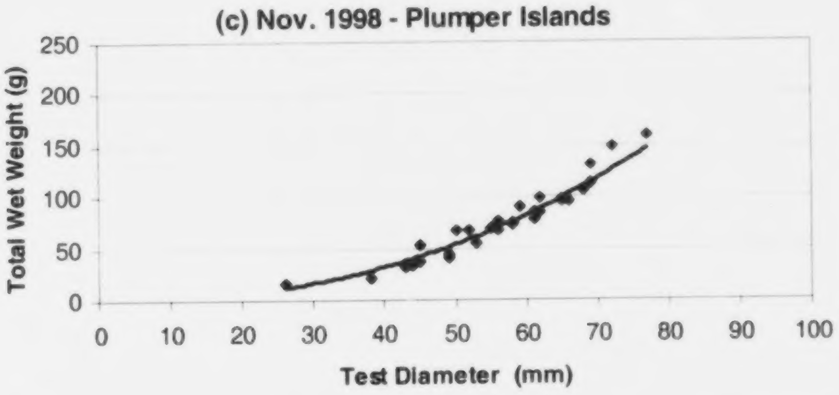

(c) Nov. 1998 - Plumper Islands

Fig. 9. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 1998 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = $0.0021(\mathrm{TD}^{2.5941})$, $R^2 = 0.9324$, n=81);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = $0.0062(\mathrm{TD}^{2.3610})$, $R^2 = 0.9267$, n=17);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = $0.0061(\mathrm{TD}^{2.3228})$, $R^2 = 0.9312$, n=30).

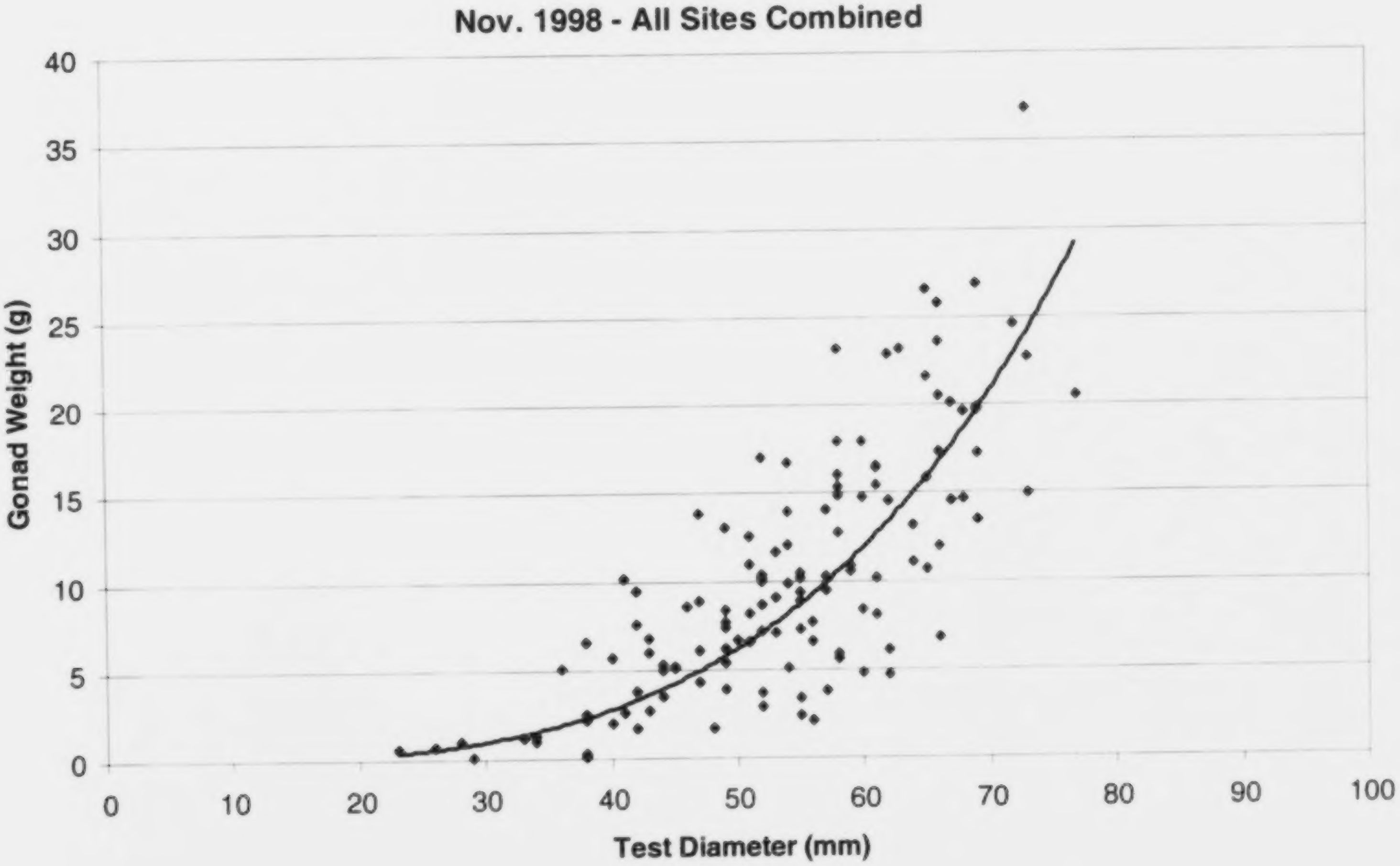
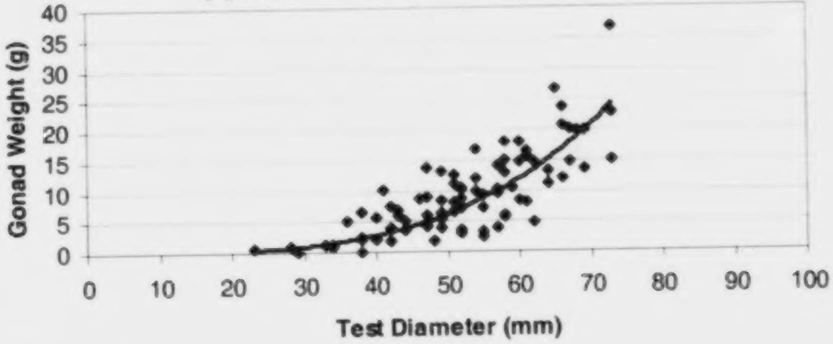
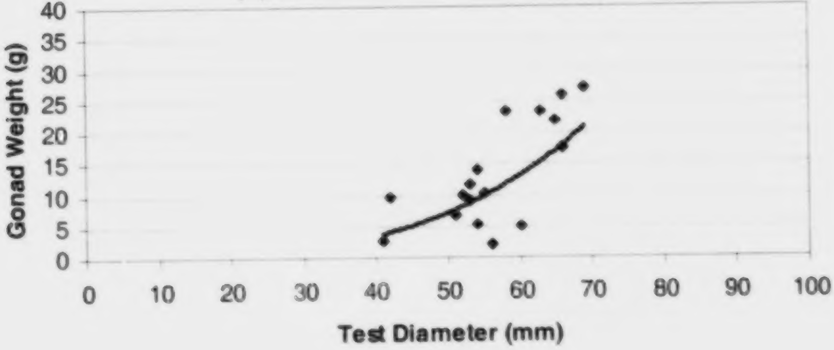


Fig. 10. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 1998, calculated from all sites combined: GONAD WEIGHT (g) = $5 \times 10^{-6}(\mathrm{TD}^{3.5930})$; $R^2 = 0.6174$, n = 128.

(a) Nov. 1998 - Stephenson Islets



(b) Nov. 1998 - Stubbs Island



(c) Nov. 1998 - Plumper Islands

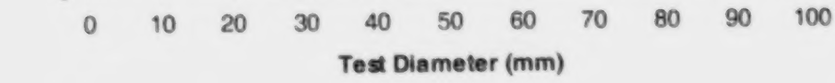


Fig. 11. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 1998 for:

(a) Stephenson Islets (GONAD WEIGHT (g) = 5 x 10^{-6} ($\mathrm{TD}^{3.6005}$), $R^2 = 0.6092$, n=81);
(b) Stubbs Island (GONAD WEIGHT (g) = 2 x 10^{-5} ($\mathrm{TD}^{3.2977}$), $R^2 = 0.3831$, n=17);
(c) Plumper Islands (GONAD WEIGHT (g) = 4 x 10^{-6} ($\mathrm{TD}^{3.6113}$), $R^2 = 0.6984$, n=30).

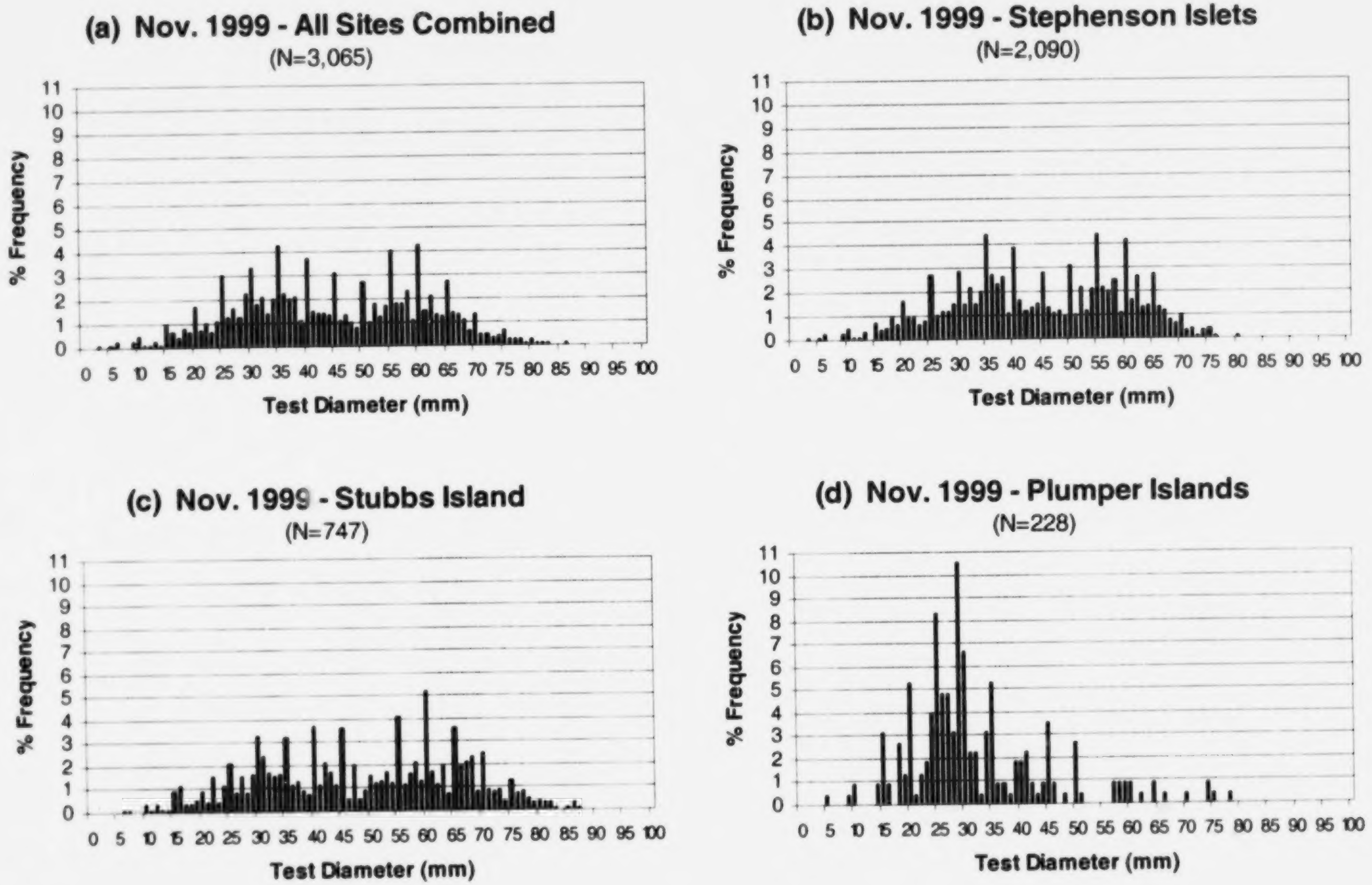


Fig. 12. Size (test diameter in millimeters) distribution of green sea urchins collected in November, 1999 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

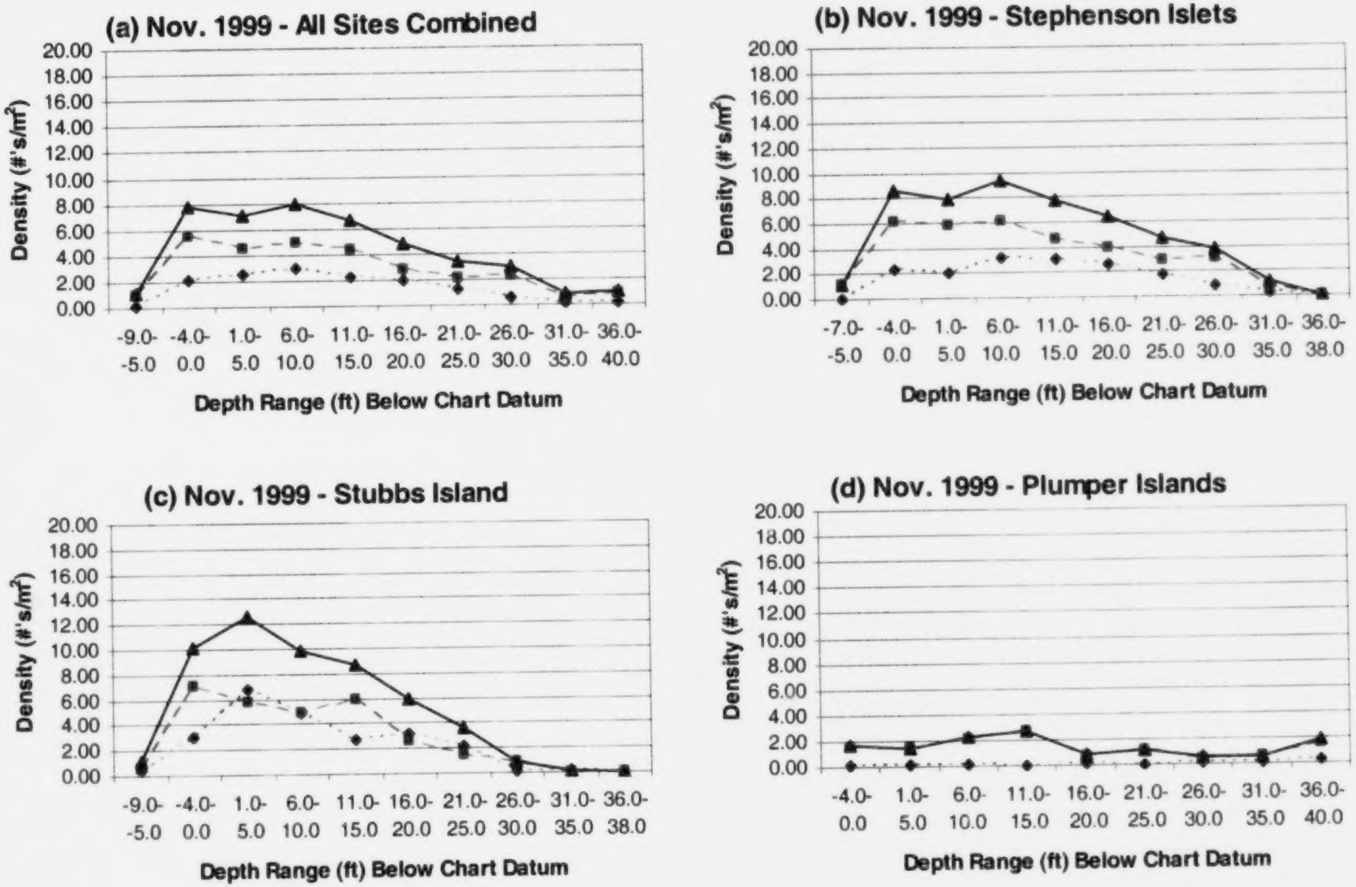
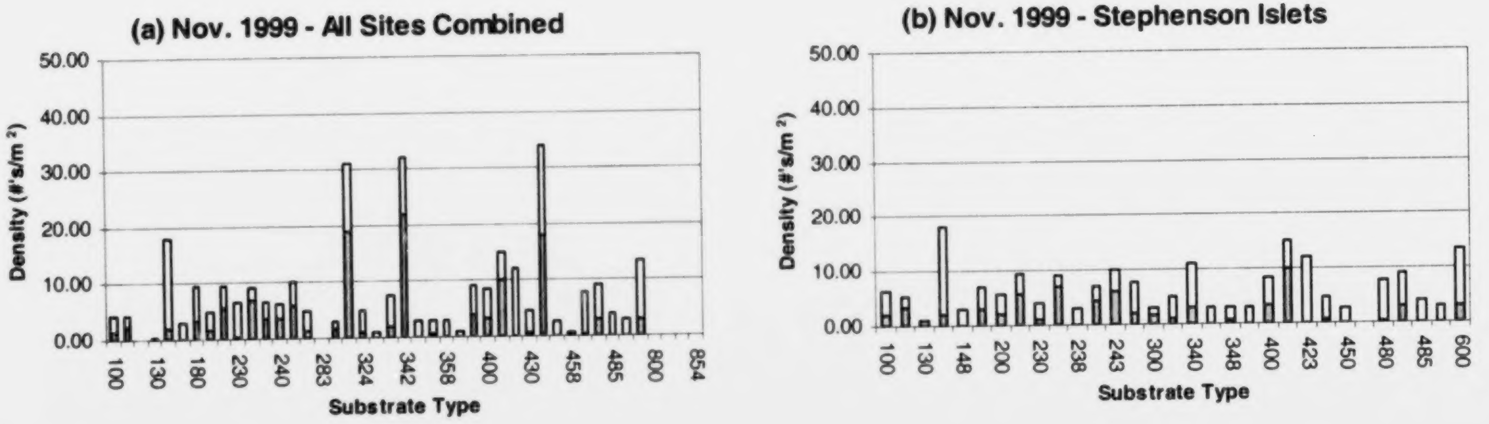
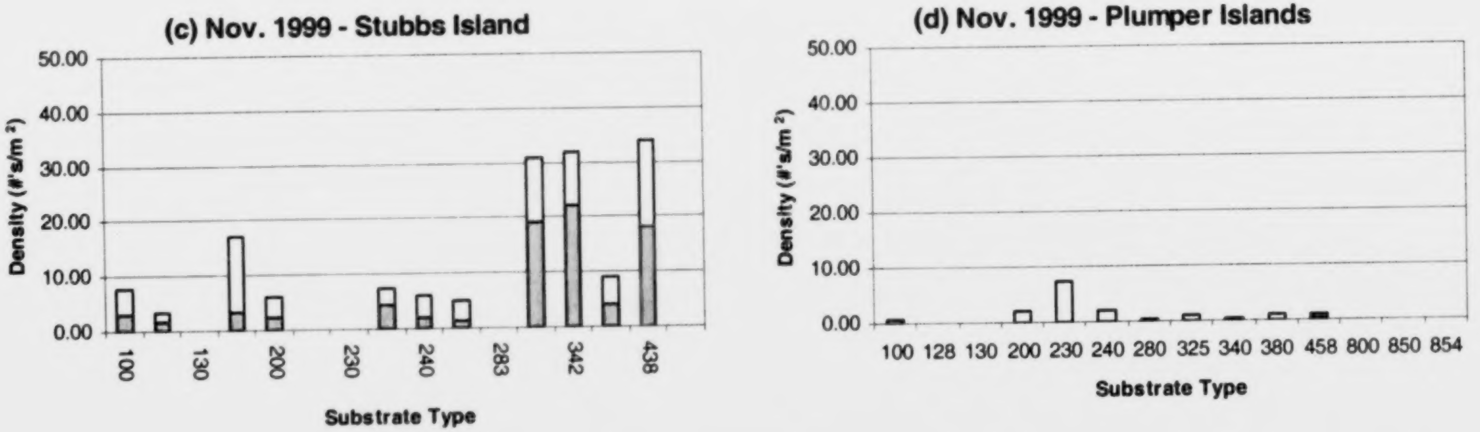


Fig. 13. November, 1999 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the unmeasured urchins ("unknowns") have been proportioned into the legal and sublegal density estimates by using the ratios from measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns. Note that the density scale is consistent for all of the "density by depth" charts between all five surveys.


(a) Nov. 1999 - All Sites Combined

(b) Nov. 1999 - Stephenson Islets


(c) Nov. 1999 - Stubbs Island

(d) Nov. 1999 - Plumper Islands

Fig. 14. November, 1999 mean densities (number per square meter) of green sea urchins of legal size (grey) and sublegal (white), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 15a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between all five surveys throughout the report.

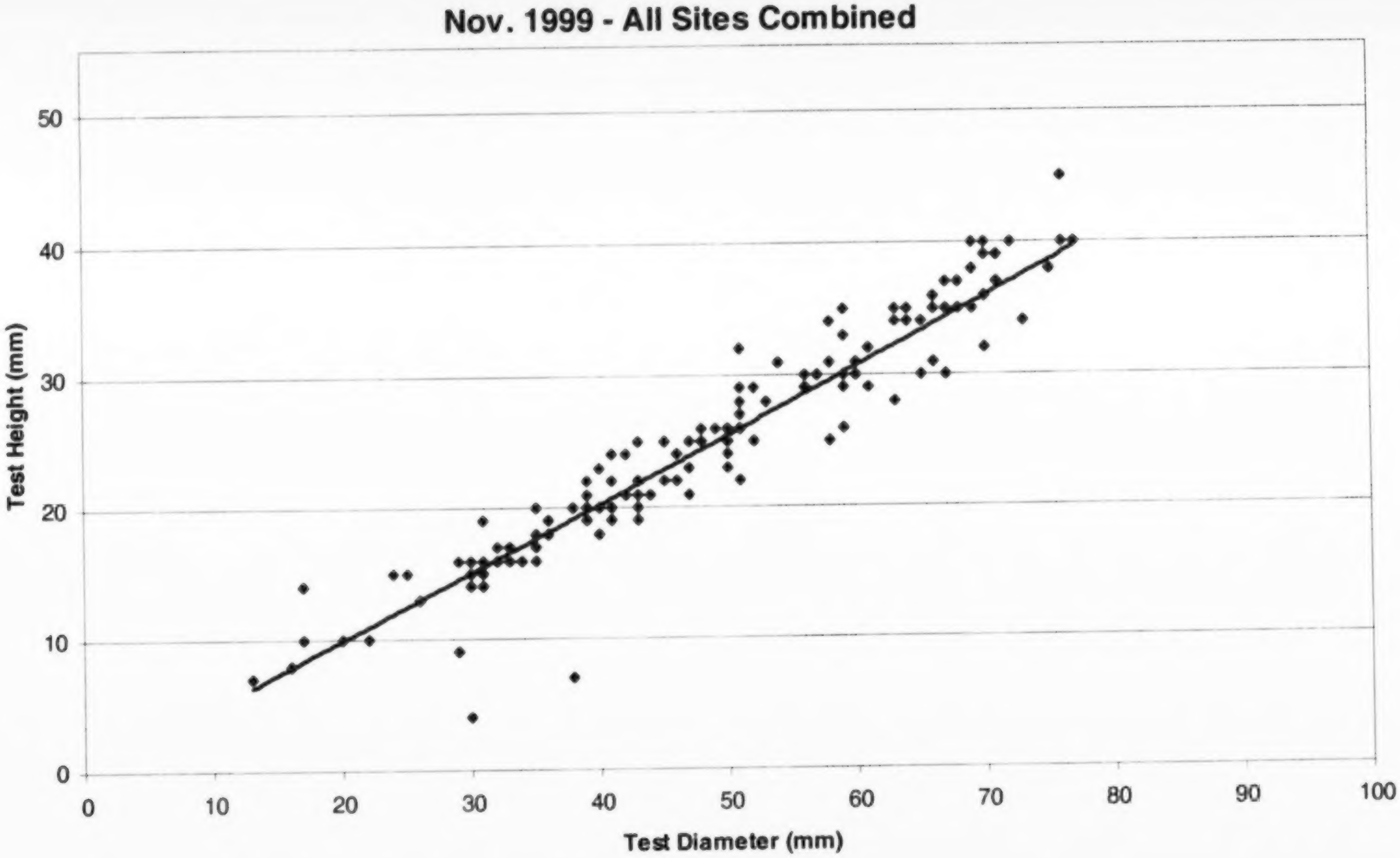
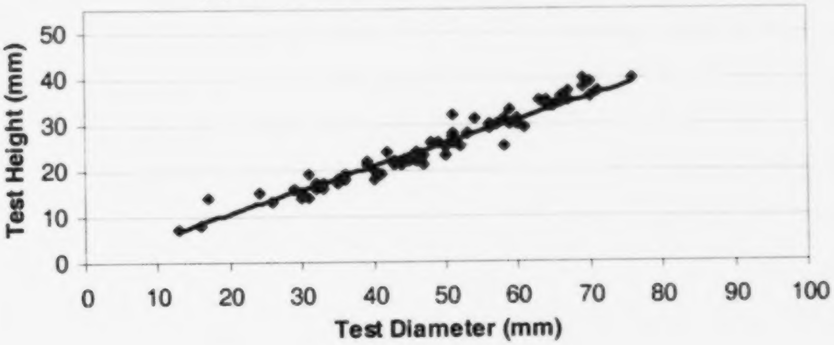
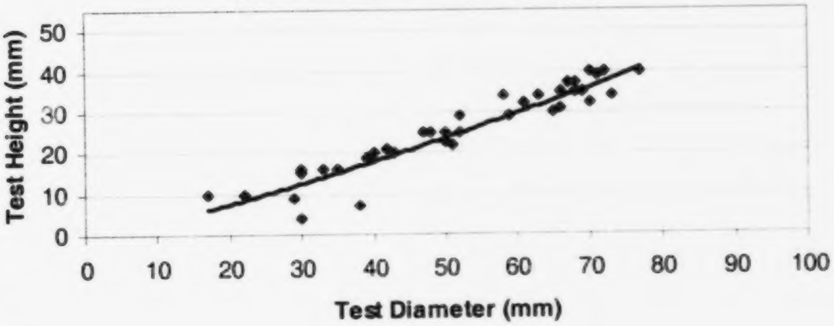


Fig. 15. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 1999, for all sites combined: TEST HEIGHT (mm) = $0.4523(\mathrm{TD}^{1.0300})$, $R^2 = 0.8279$, n=158.

(a) Nov. 1999 - Stephenson Islets



(b) Nov. 1999 - Stubbs Island



(c) Nov. 1999 - Plumper Islands

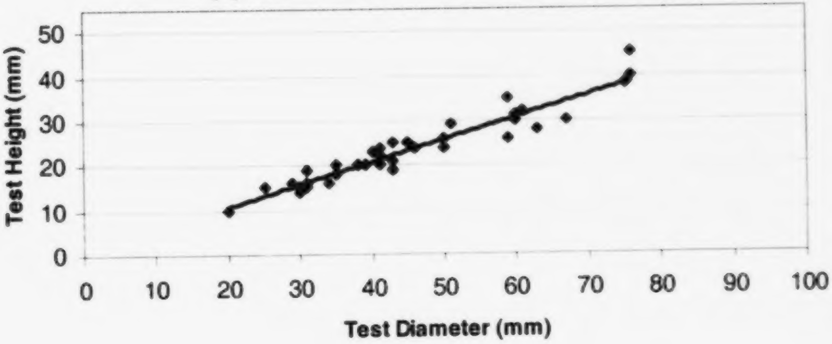


Fig. 16. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 1999 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.5794(\text{TD}^{0.9715})$, $R^2 = 0.9399$, n=83);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.1772(\text{TD}^{1.2505})$, $R^2 = 0.7412$, n=37);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.5912(\text{TD}^{0.9654})$, $R^2 = 0.9224$, n=38).

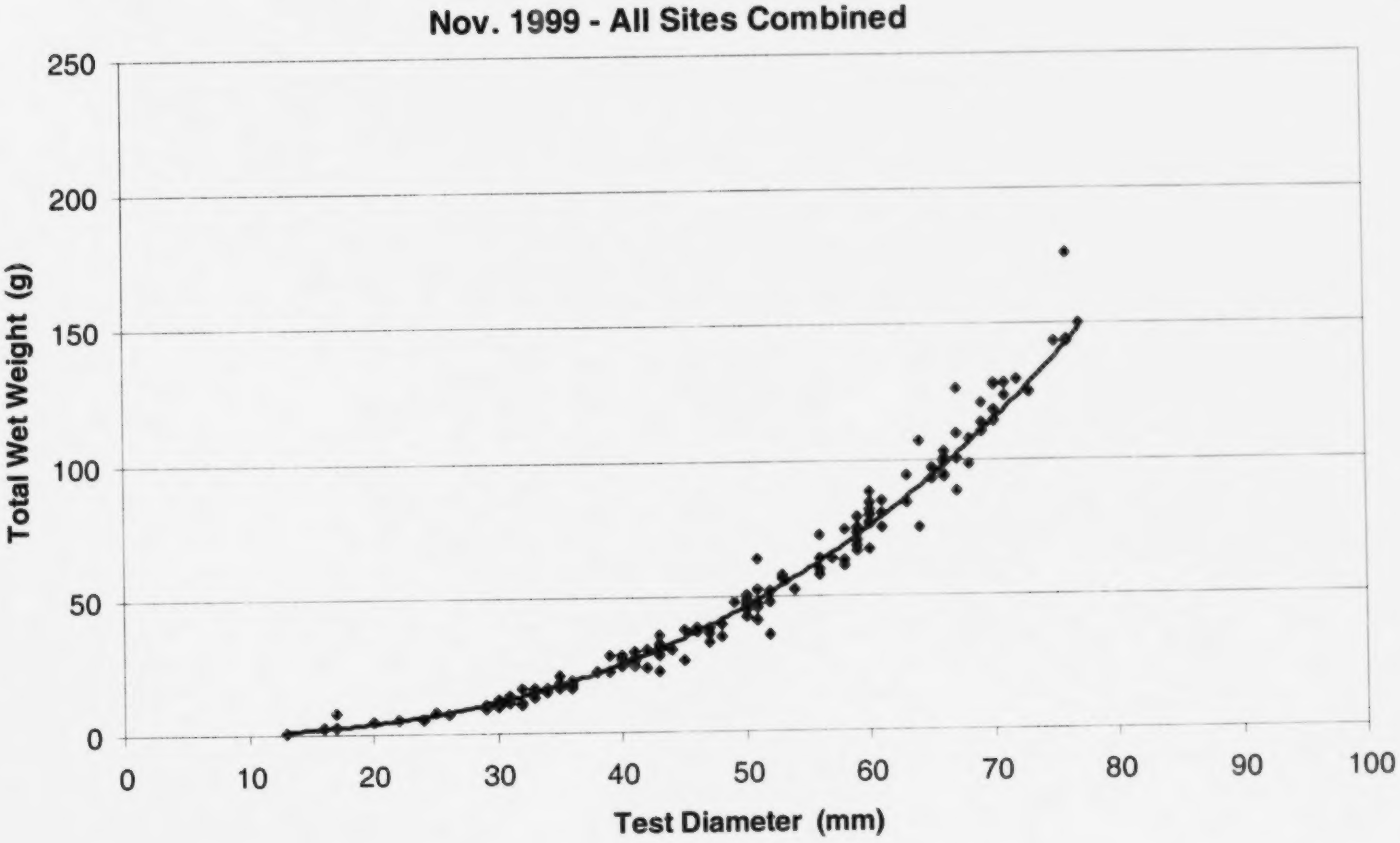
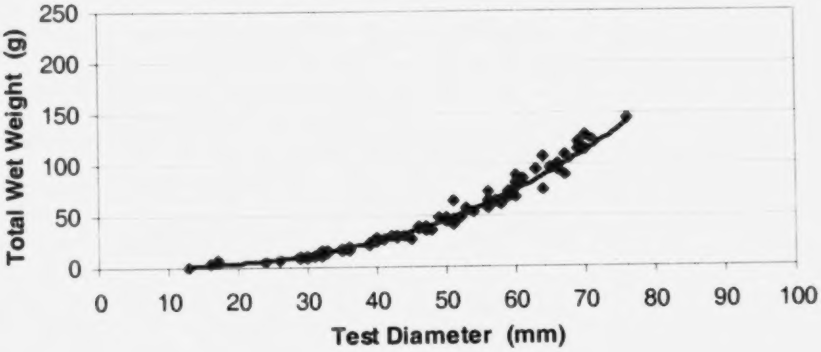
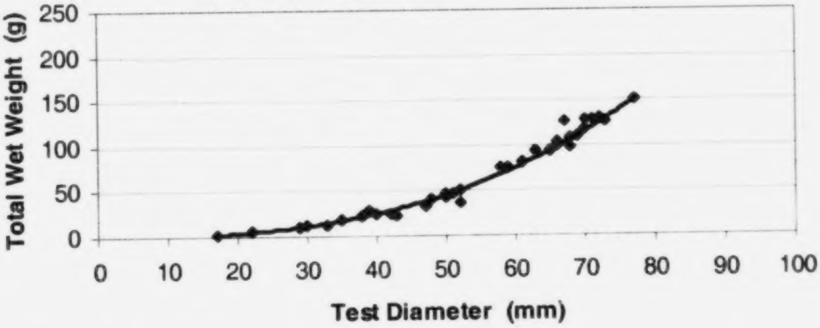


Fig. 17. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 1999, for all sites combined: TOTAL WET WEIGHT (g) = $0.0012(\mathrm{TD}^{2.6926})$, $R^2 = 0.9775$, n=158.


(a) Nov. 1999 - Stephenson Islets


(b) Nov. 1999 - Stubbs Island

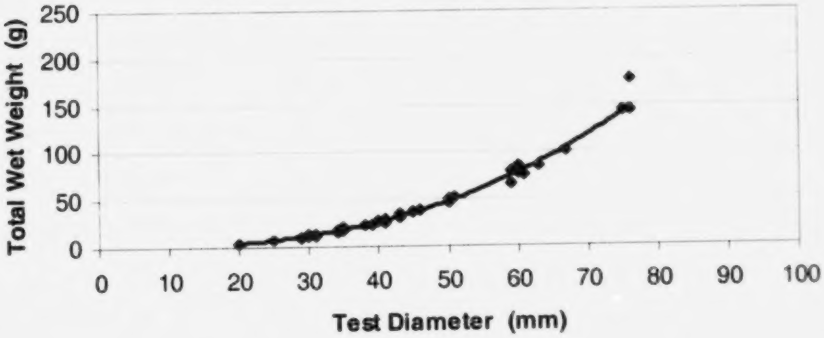

(c) Nov. 1999 - Plumper Islands

Fig. 18. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 1999 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = $0.0013(\mathrm{TD}^{2.6842})$, $R^2 = 0.9668$, n=83);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = $0.0010(\mathrm{TD}^{2.7526})$, $R^2 = 0.9885$, n=37);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = $0.0014(\mathrm{TD}^{2.6660})$, $R^2 = 0.9934$, n=38).

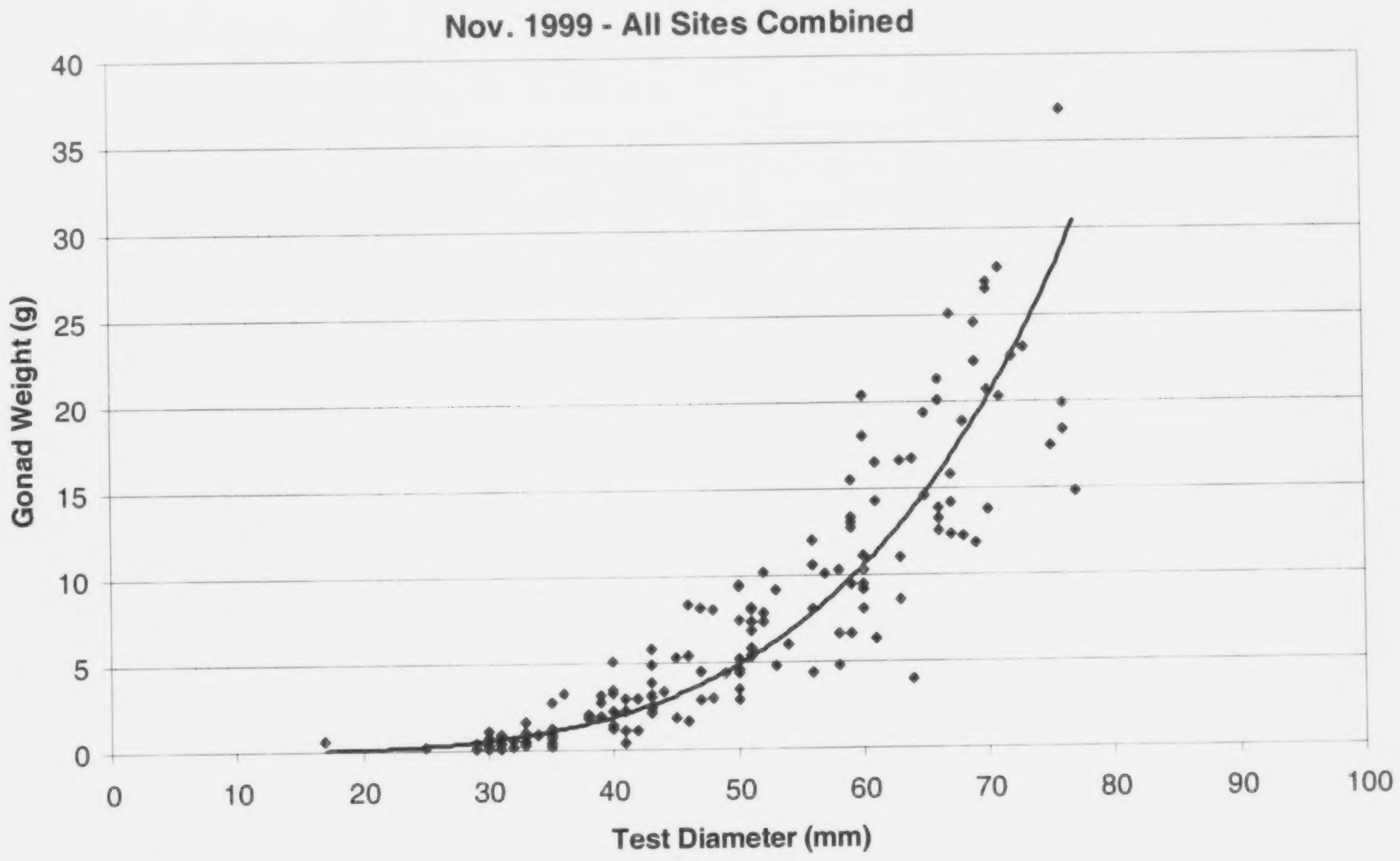
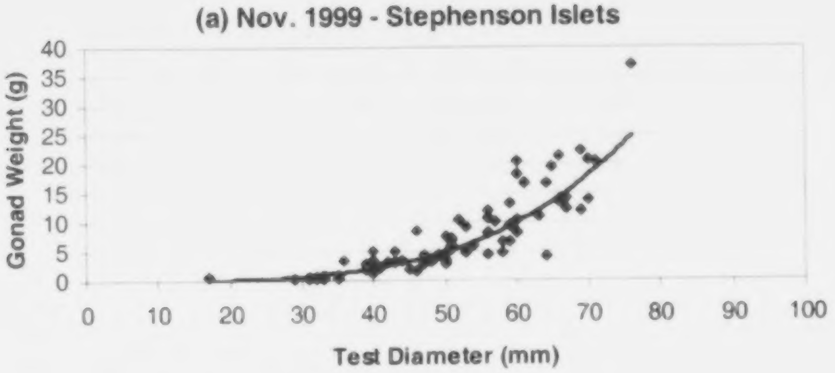
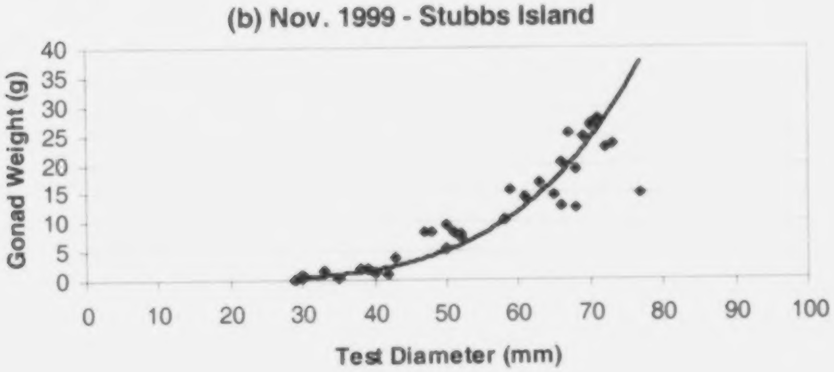


Fig. 19. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 1999, calculated from all sites combined: GONAD WEIGHT (g) = $3 \times 10^{-7}(\mathrm{TD}^{4.2387})$; $R^2 = 0.8132$, $n = 141$.


(a) Nov. 1999 - Stephenson Islets


(b) Nov. 1999 - Stubbs Island

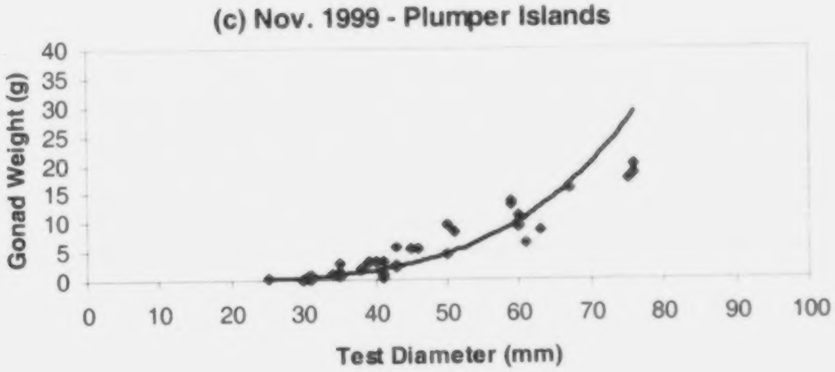
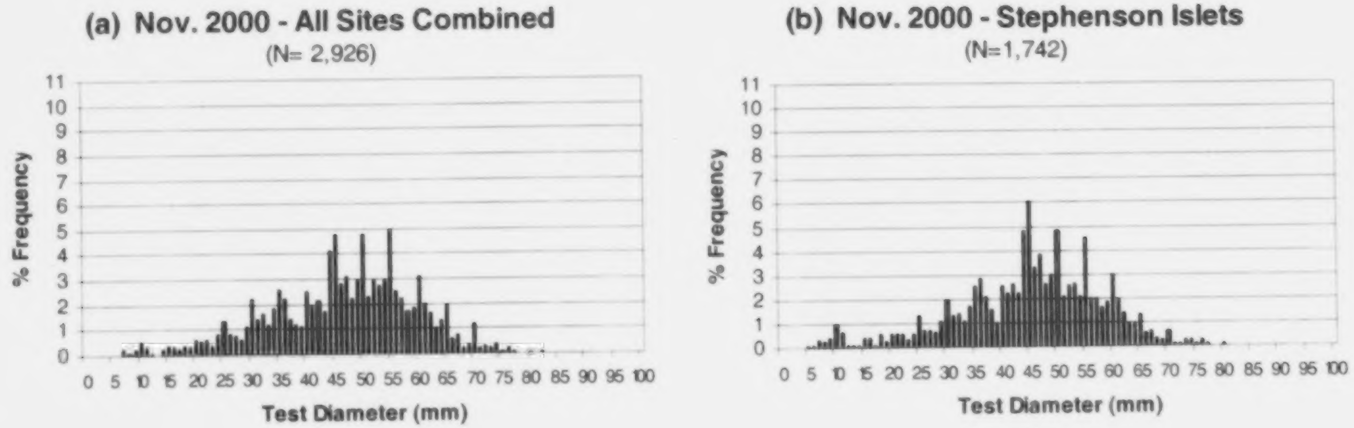
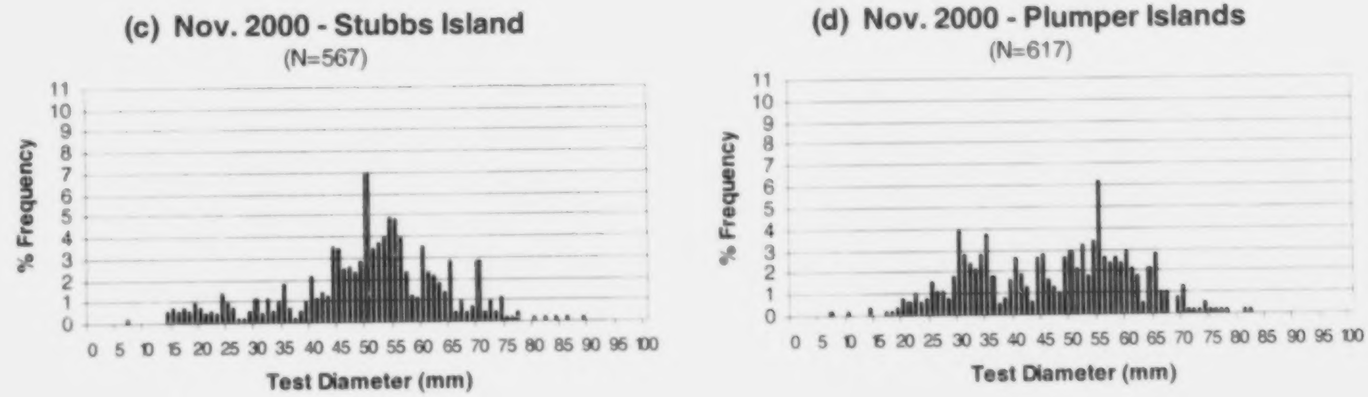

(c) Nov. 1999 - Plumper Islands

Fig. 20. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 1999 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 1 x 10^{-6} ($\text{TD}^{3.8609}$), $R^2 = 0.7944$, n=73);
(b) Stubbs Island (GONAD WEIGHT (g) = 6 x 10^{-8} ($\text{TD}^{4.6452}$), $R^2 = 0.8671$, n=35);
(c) Plumper Islands (GONAD WEIGHT (g) = 1 x 10^{-7} ($\text{TD}^{4.4253}$), $R^2 = 0.7869$, n=33).


(a) Nov. 2000 - All Sites Combined
(N= 2,926)

(b) Nov. 2000 - Stephenson Islets
(N=1,742)


(c) Nov. 2000 - Stubbs Island
(N=567)

(d) Nov. 2000 - Plumper Islands
(N=617)

Fig. 21. Size (test diameter in millimeters) distribution of green sea urchins collected in November, 2000 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

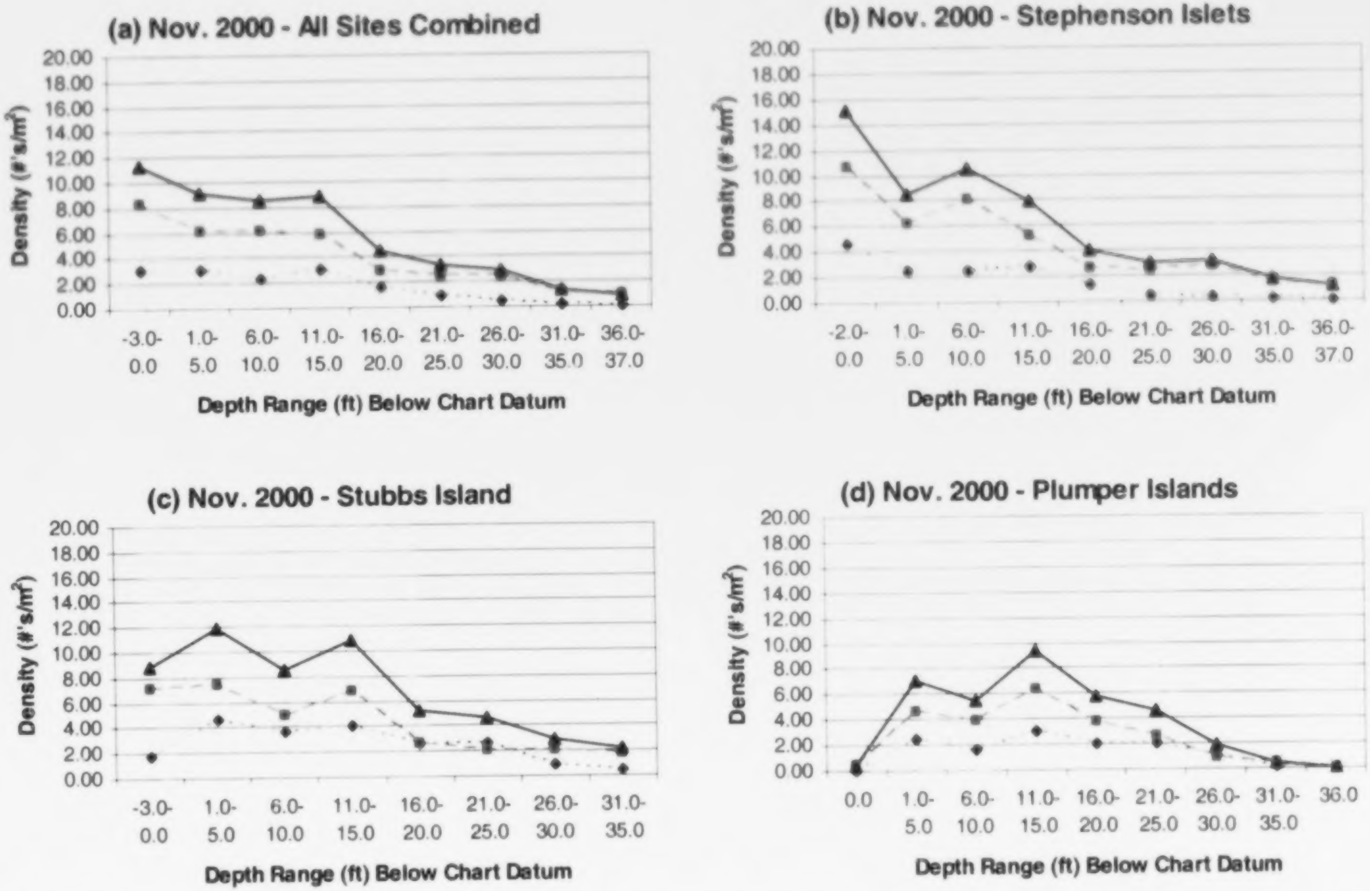


Fig. 22. November, 2000 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the unmeasured urchins ("unknowns") have been proportioned into the legal and sublegal density estimates by using the ratios from measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns. Note that the density scale is consistent for all of the "density by depth" charts between all five surveys.

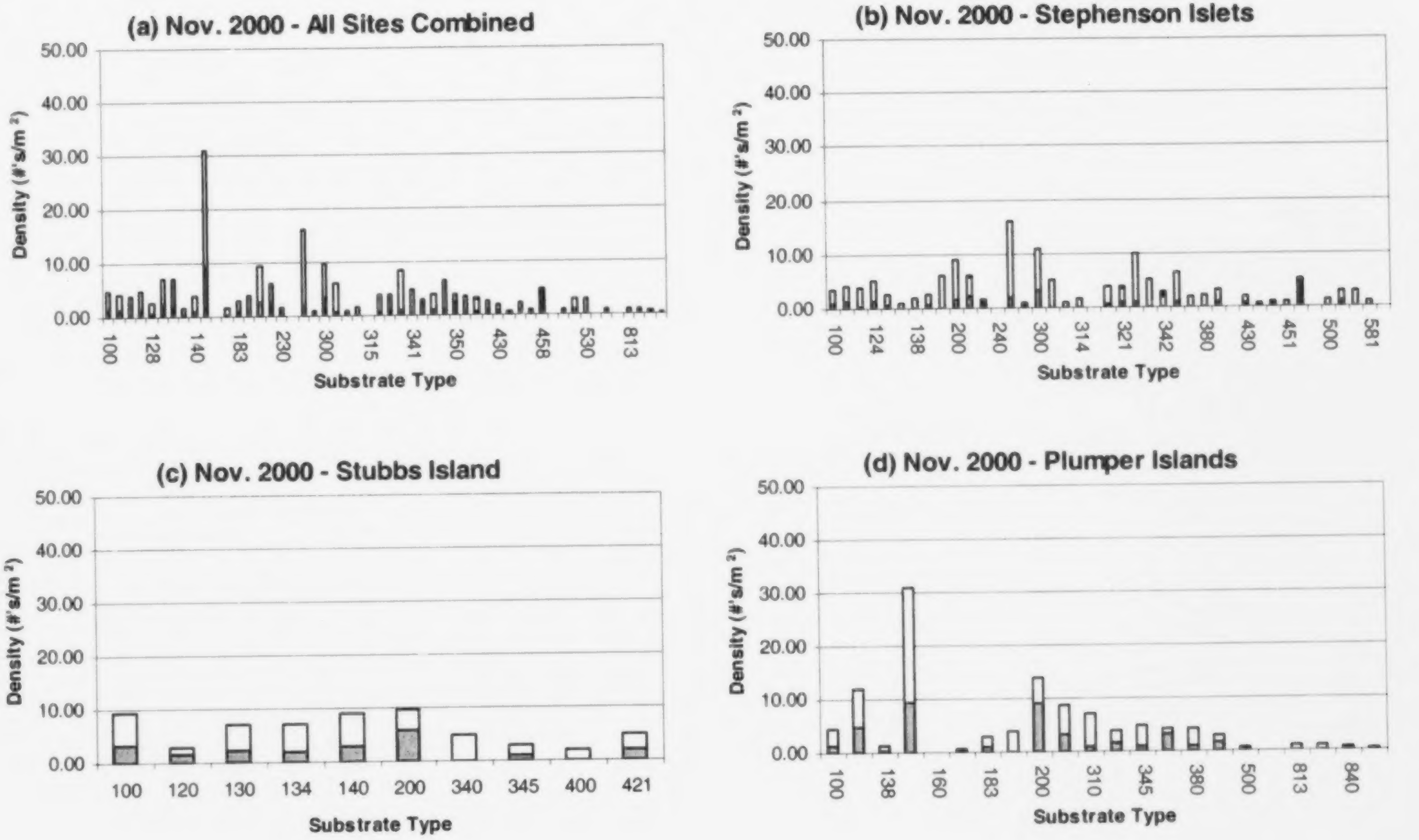


Fig. 23. November, 2000 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal (white), and unknown size (black), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 21a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between all five surveys throughout the report.

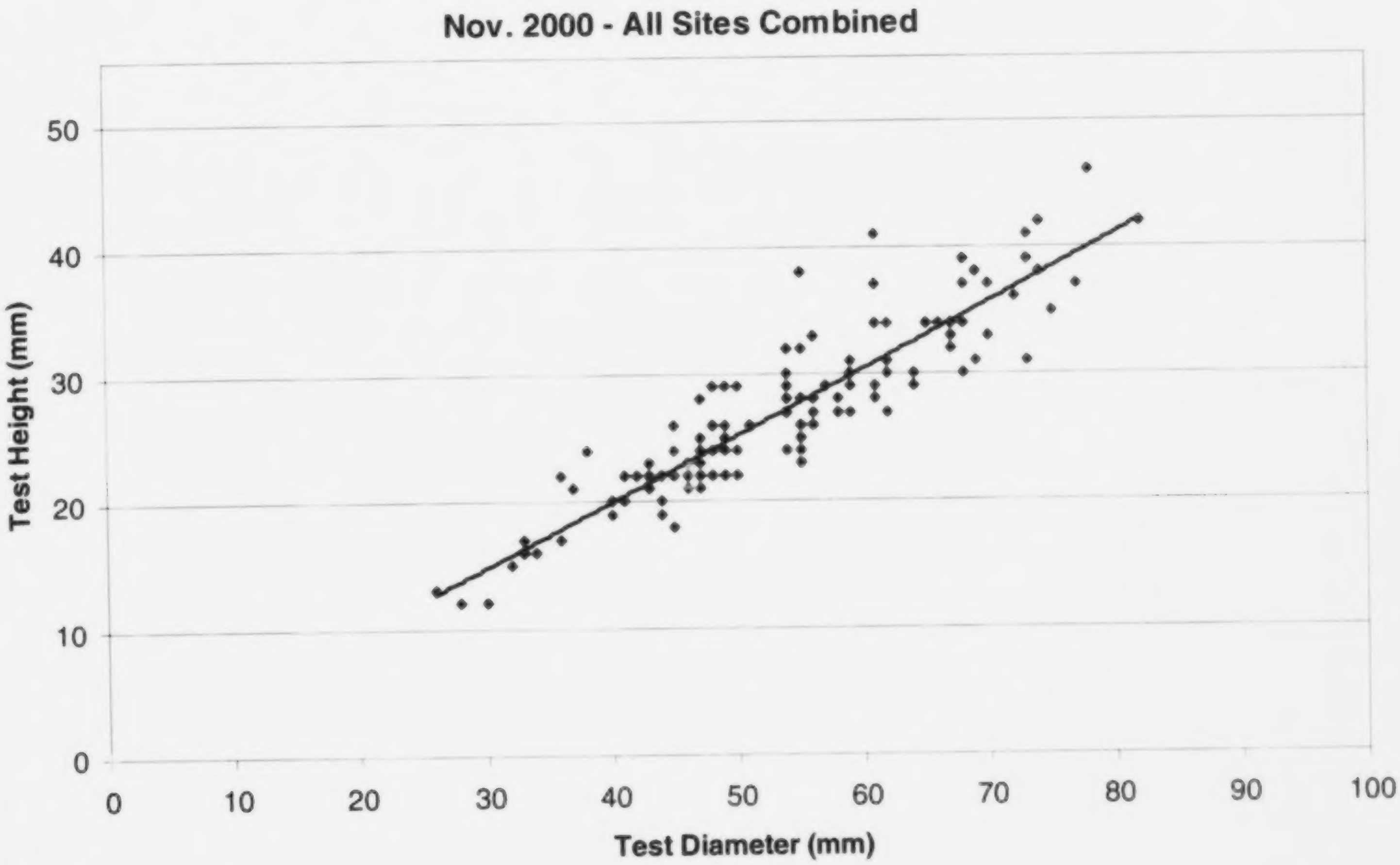
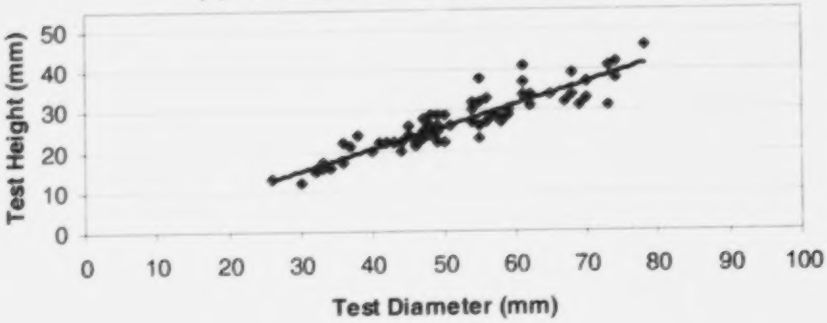
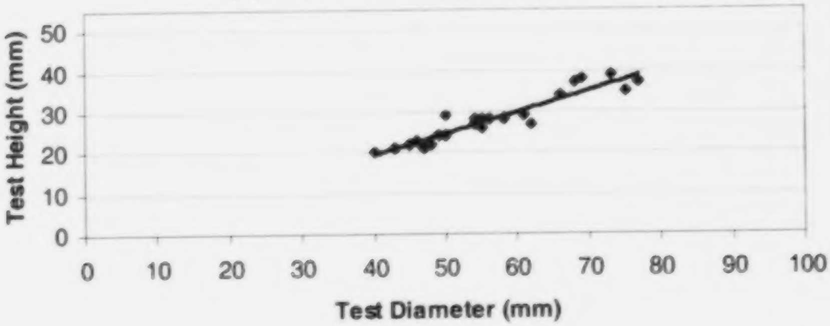


Fig. 24. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 2000, for all sites combined: TEST HEIGHT (mm) = $0.4285(\mathrm{TD}^{1.0411})$, $R^2 = 0.8484$, n=123.

(a) Nov. 2000 - Stephenson Islets



(b) Nov. 2000 - Stubbs Island



(c) Nov. 2000 - Plumper Islands

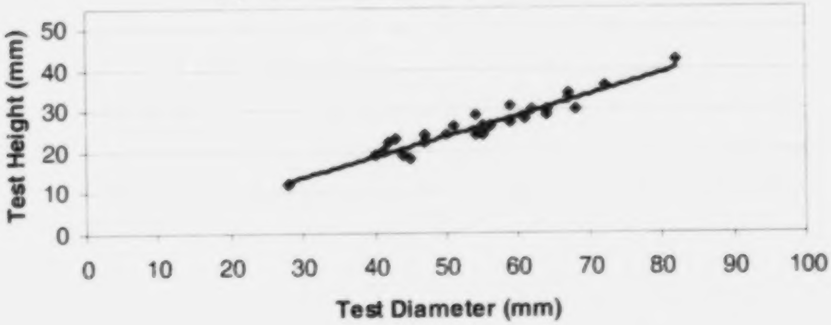


Fig. 25. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 2000 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = 0.4107($\text{TDD}^{1.0599}$), $R^2 = 0.8494$, n=70);
(b) Stubbs Island (TEST HEIGHT (mm) = 0.3954($\text{TD}^{1.0558}$), $R^2 = 0.9020$, n=25);
(c) Plumper Islands (TEST HEIGHT (mm) = 0.3659($\text{TD}^{1.0661}$), $R^2 = 0.9149$, n=28).

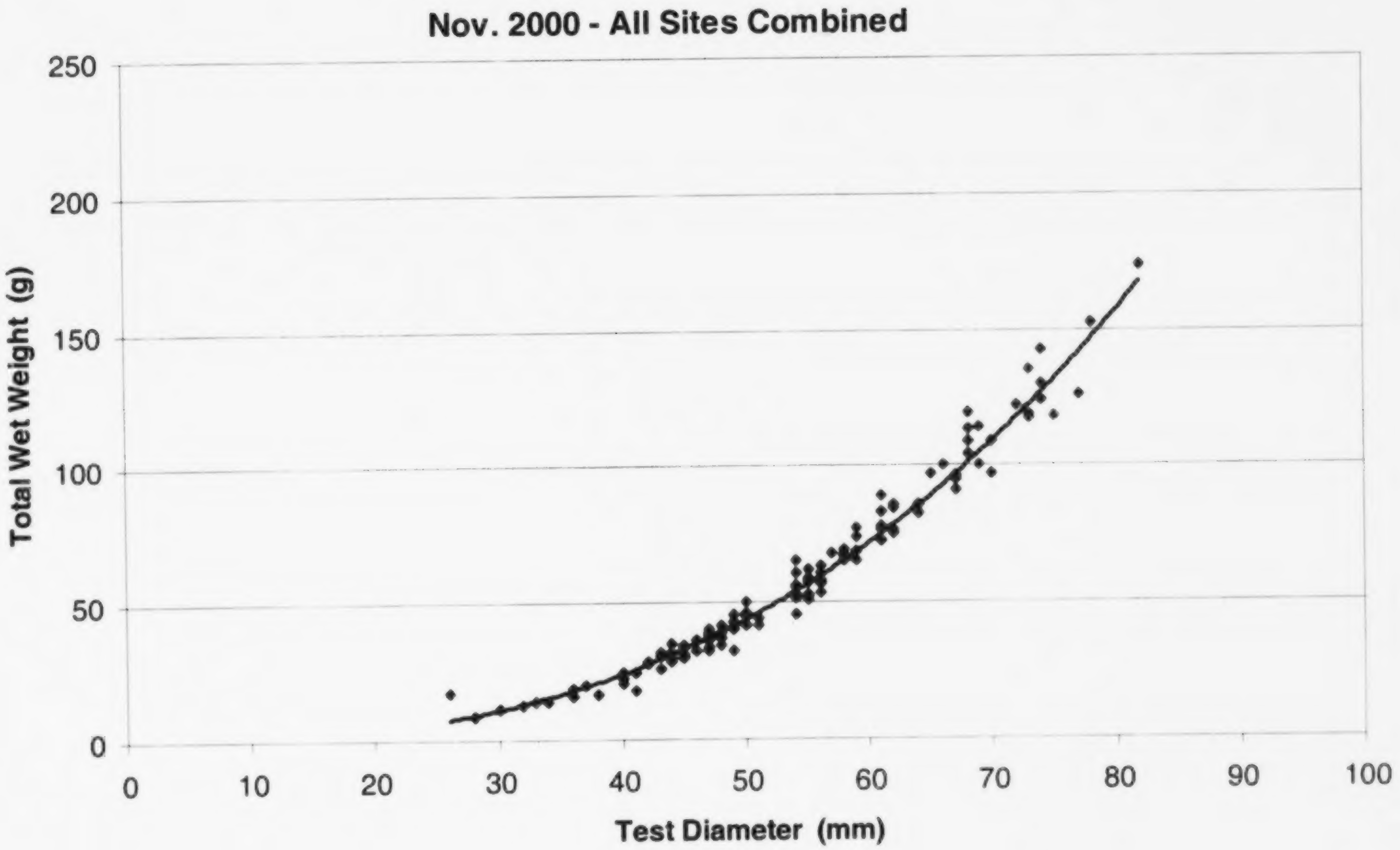
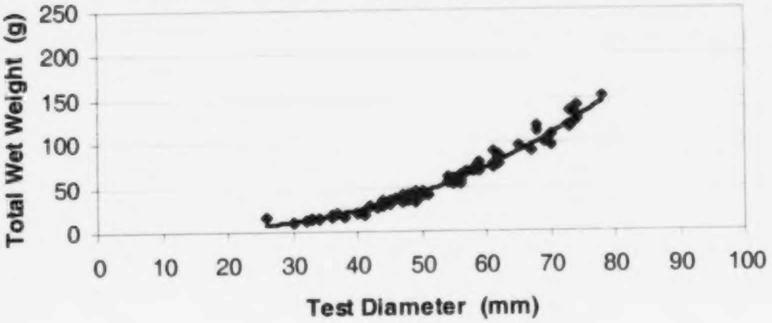
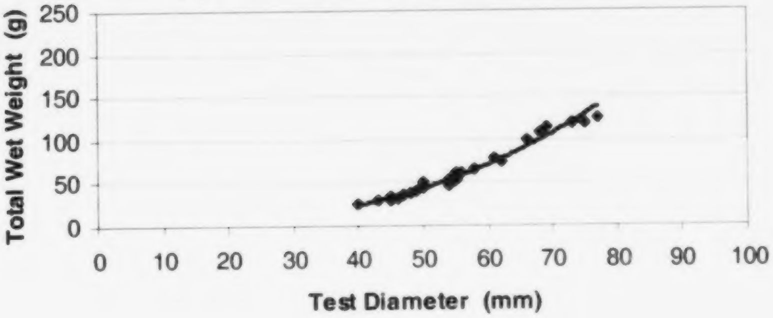


Fig. 26. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 2000, for all sites combined: TOTAL WET WEIGHT (g) = $0.0011(\mathrm{TD}^{2.7139})$, $R^2 = 0.9669$, n=123.

(a) Nov. 2000 - Stephenson Islets



(b) Nov. 2000 - Stubbs Island



(c) Nov. 2000 - Plumper Islands

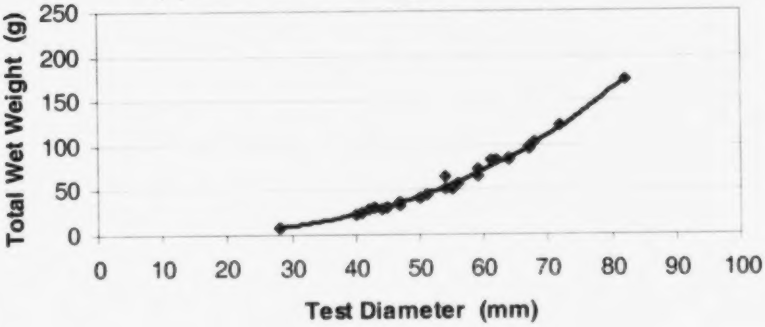


Fig. 27. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 2000 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = 0.0012($TD^{2.6935}$), $R^2 = 0.9576$, n=70);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = 0.0012($TD^{2.6758}$), $R^2 = 0.9774$, n=25);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = 0.0007($TD^{2.8233}$), $R^2 = 0.9883$, n=28).

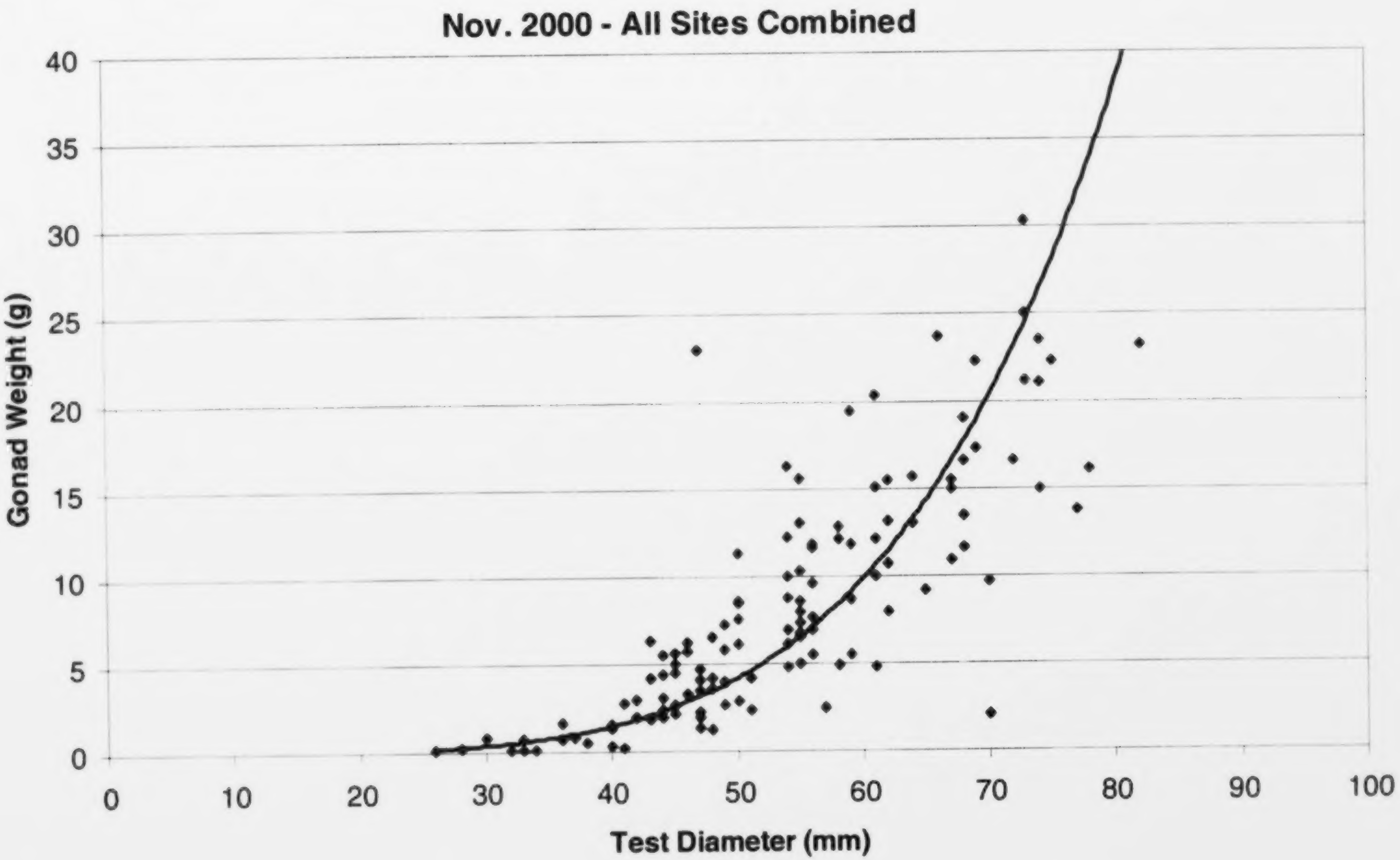
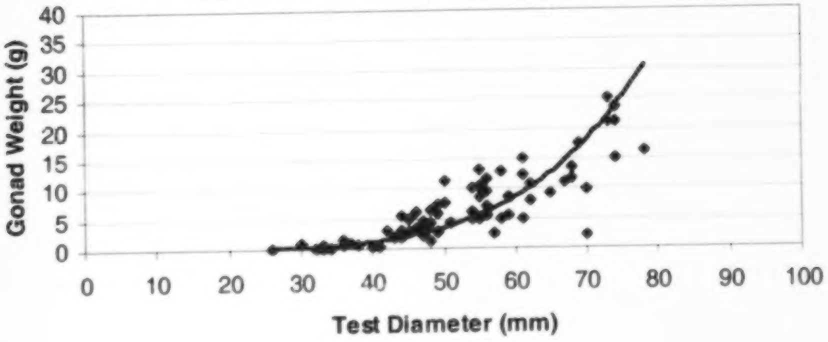
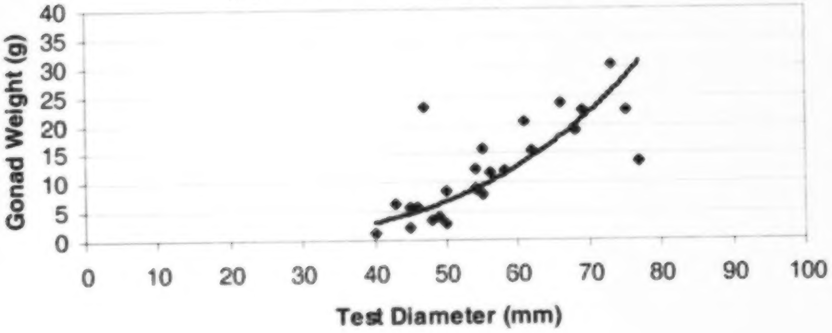


Fig. 28. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 2000, calculated from all sites combined: GONAD WEIGHT (g) = $5 \times 10^{-8}(\mathrm{TD}^{4.6858})$; $R^2 = 0.7222$, $n = 123$.

(a) Nov. 2000 - Stephenson Islets



(b) Nov. 2000 - Stubbs Island



(c) Nov. 2000 - Plumper Islands

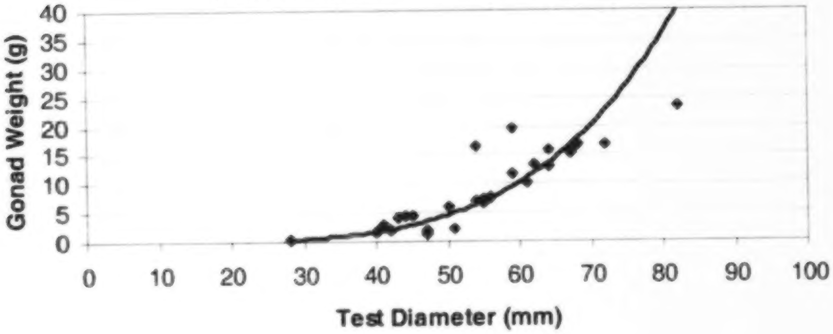
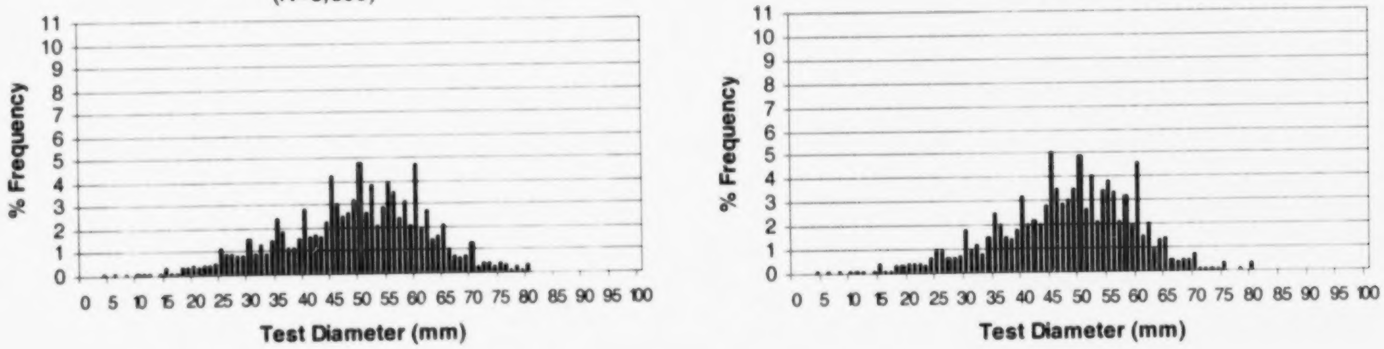
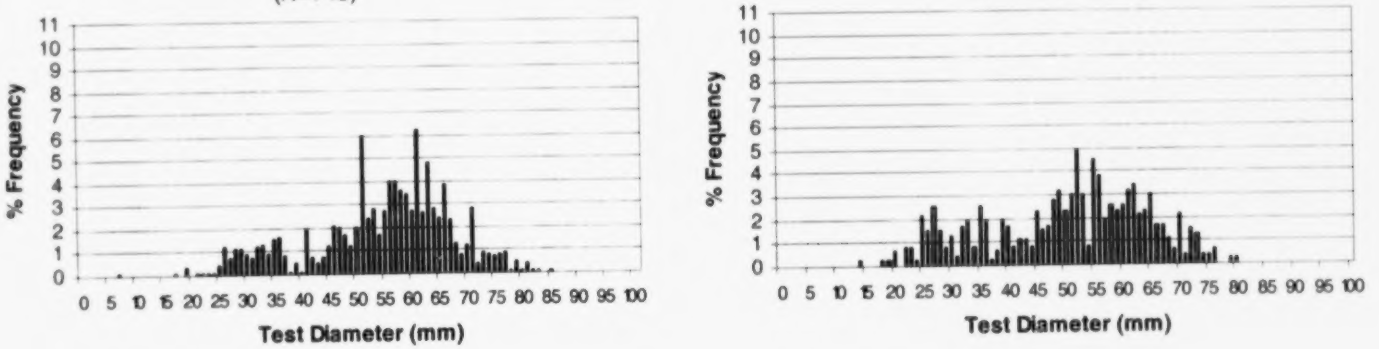


Fig. 29. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 2000 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 2 x 10^{-8} ($\text{TD}^{4.8173}$), $R^2 = 0.7269$, n=63);
(b) Stubbs Island (GONAD WEIGHT (g) = 7 x 10^{-6} ($\text{TD}^{3.5189}$), $R^2 = 0.6097$, n=25);
(c) Plumper Islands (GONAD WEIGHT (g) = 2 x 10^{-7} ($\text{TD}^{4.4039}$), $R^2 = 0.8332$, n=28).



(a) Nov. 2001 - All Sites Combined (N=3,899)

(b) Nov. 2001 - Stephenson Islets (N=2,683)



(c) Nov. 2001 - Stubbs Island (N=745)

(d) Nov. 2001 - Plumper Islands (N=471)

Fig. 30. Size (test diameter in millimeters) distribution of green sea urchins collected in November, 2001 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

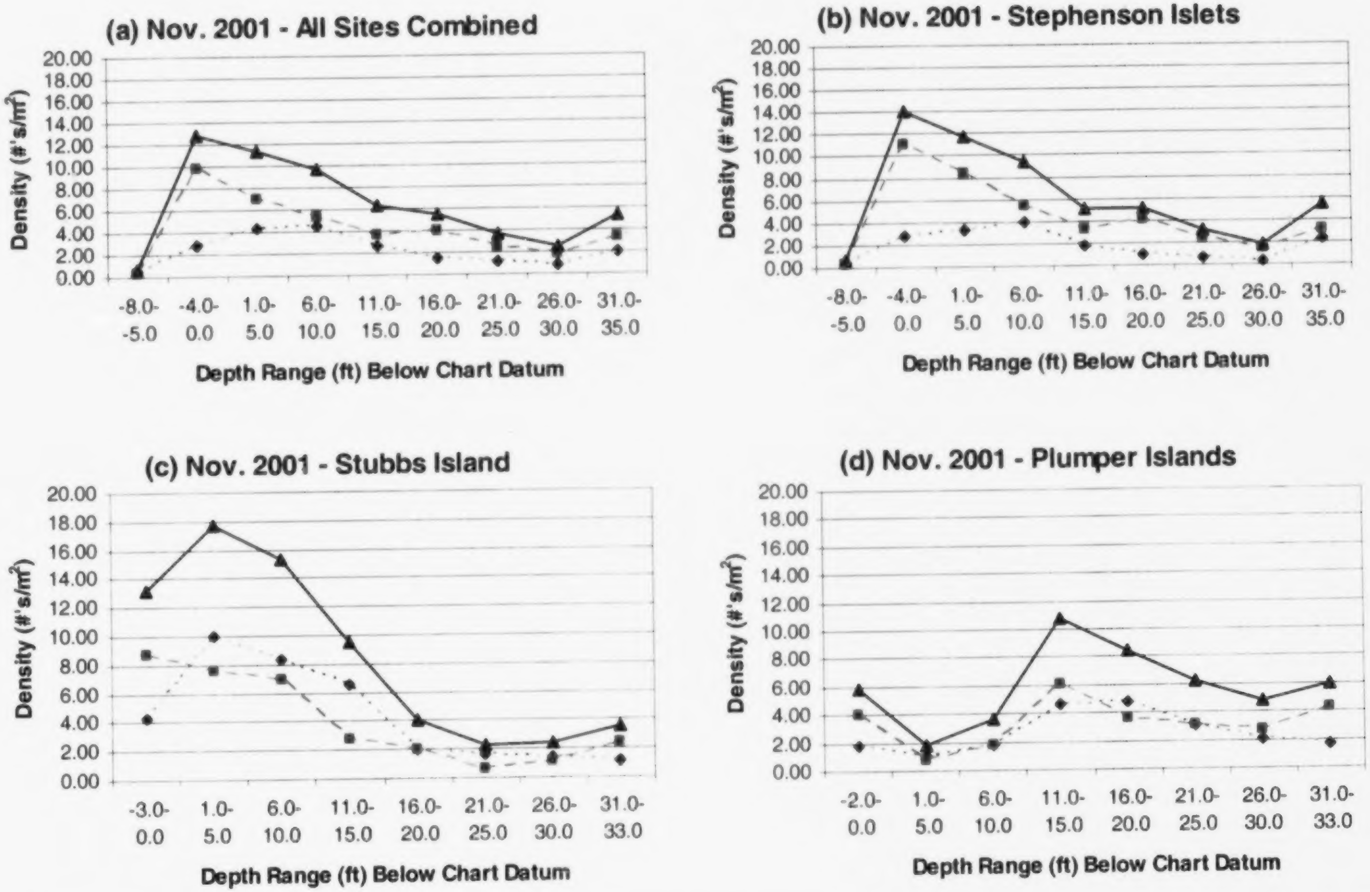


Fig. 31. November, 2001 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the unmeasured urchins ("unknowns") have been proportioned into the legal and sublegal density estimates by using the ratios from measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns. Note that the density scale is consistent for all of the "density by depth" charts between all five surveys.

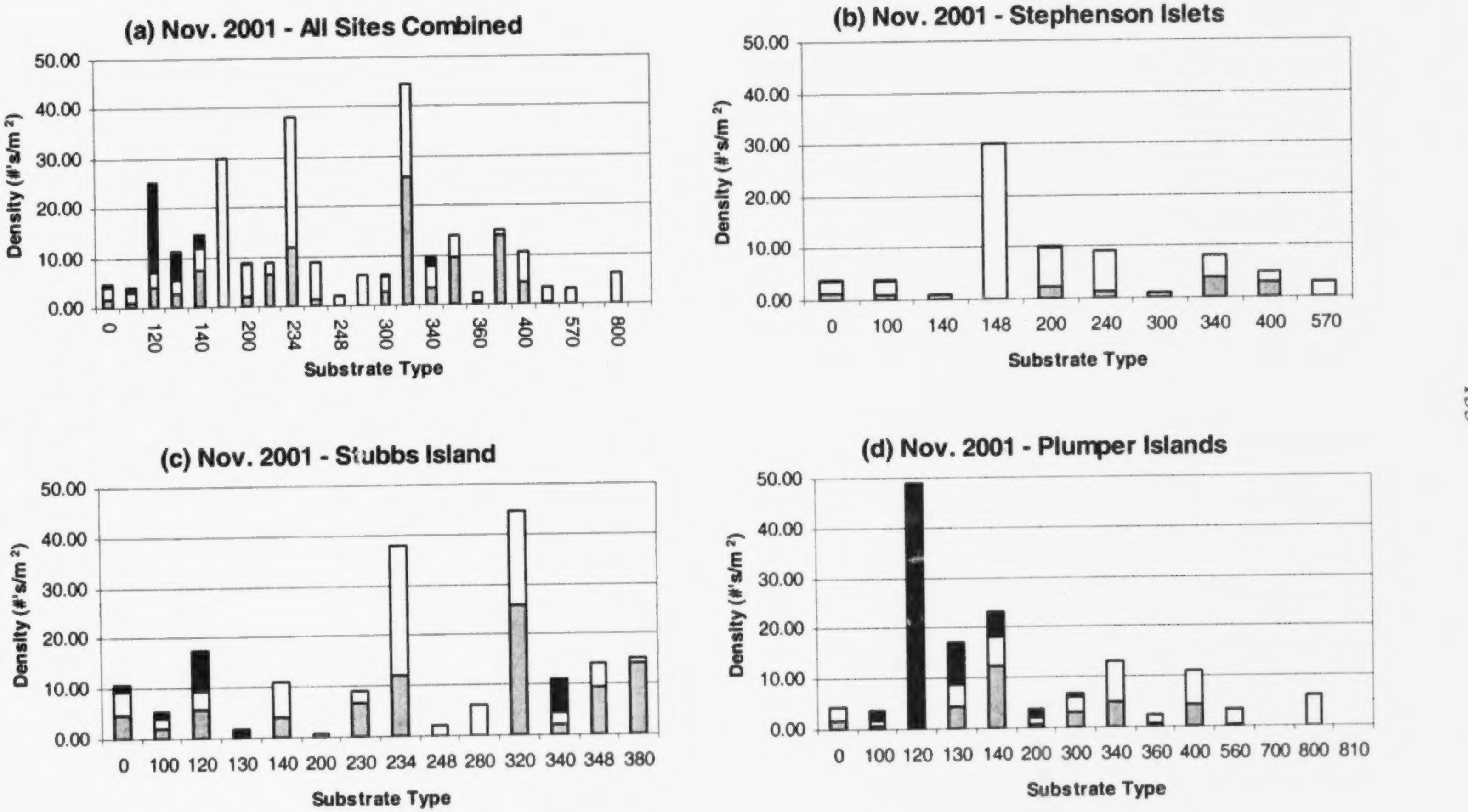


Fig. 32. November, 2001 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal size (white), and unknown size (black), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 26a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between all five surveys throughout the report.

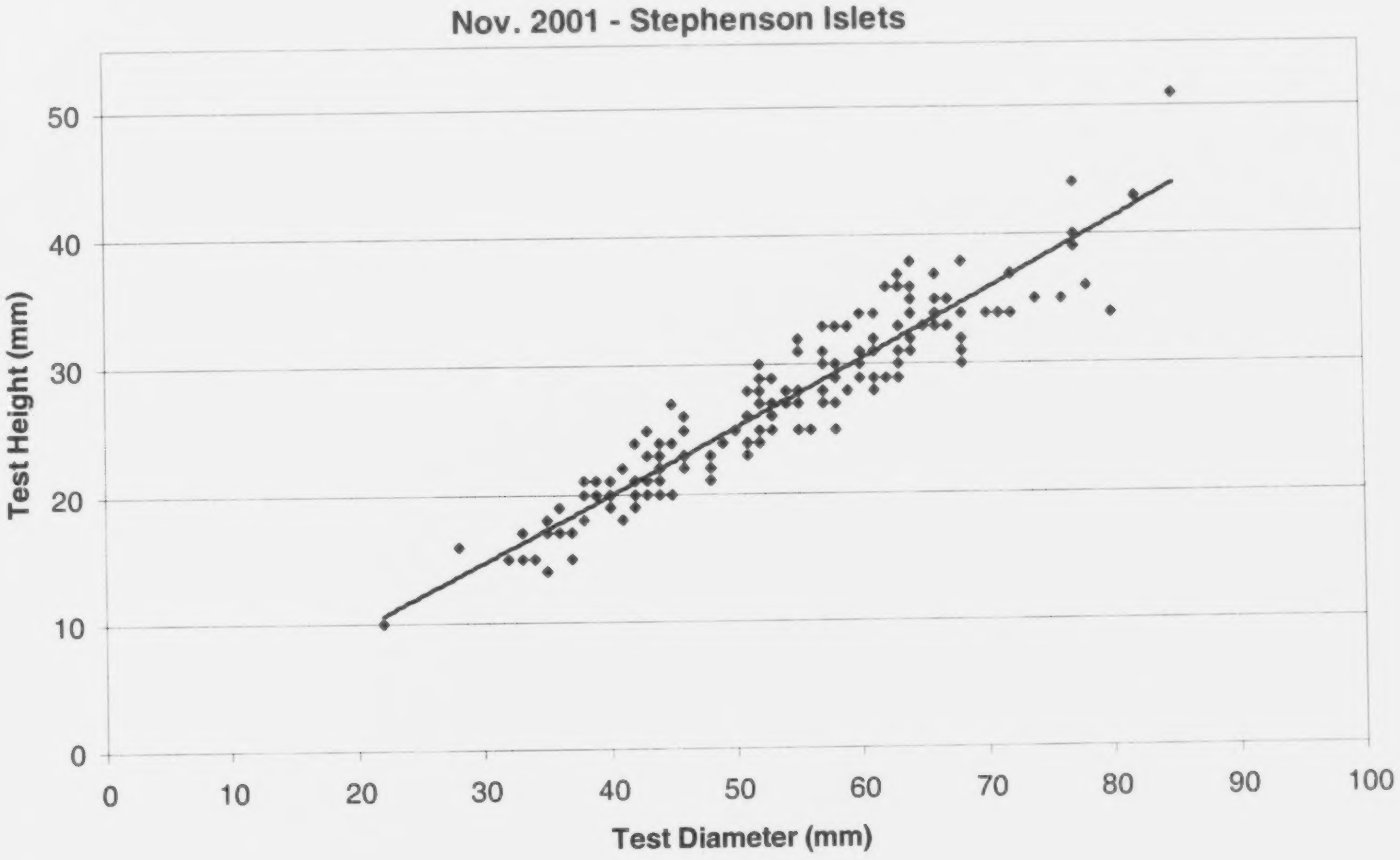
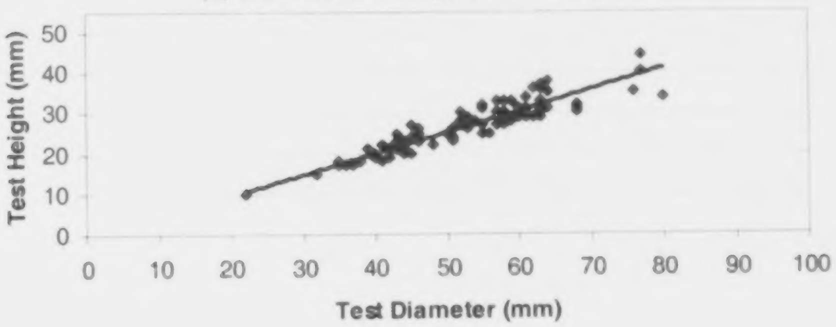
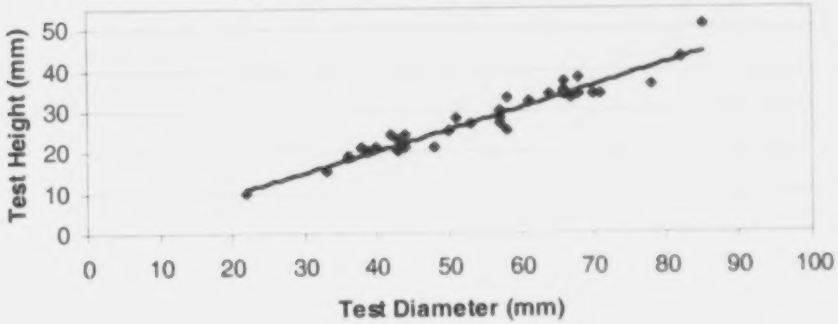


Fig. 33. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in November, 2001, for all sites combined: TEST HEIGHT (mm) = $0.4089(\text{TD}^{1.0528})$, $R^2 = 0.9065$, n=167.

(a) Nov. 2001 - Stephenson Islets



(b) Nov. 2001 - Stubbs Island



(c) Nov. 2001 - Plumper Islands

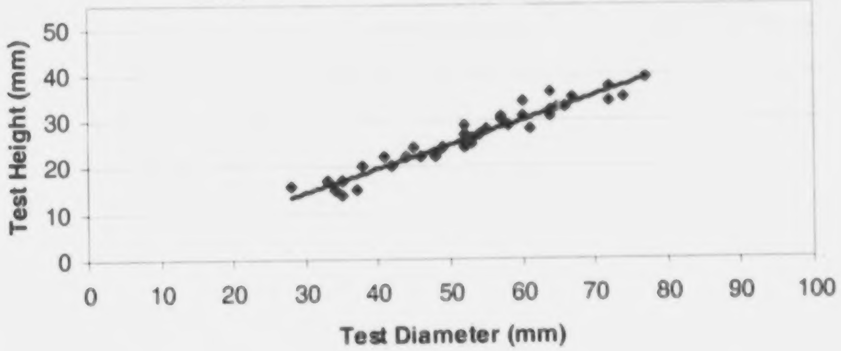


Fig. 34. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in November, 2001 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.4196(\text{TD}^{1.0467})$, $R^2 = 0.8771$, n=88);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.4163(\text{TD}^{1.0508})$, $R^2 = 0.9382$, n=37);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.3959(\text{TD}^{1.0577})$, $R^2 = 0.9226$, n=42).

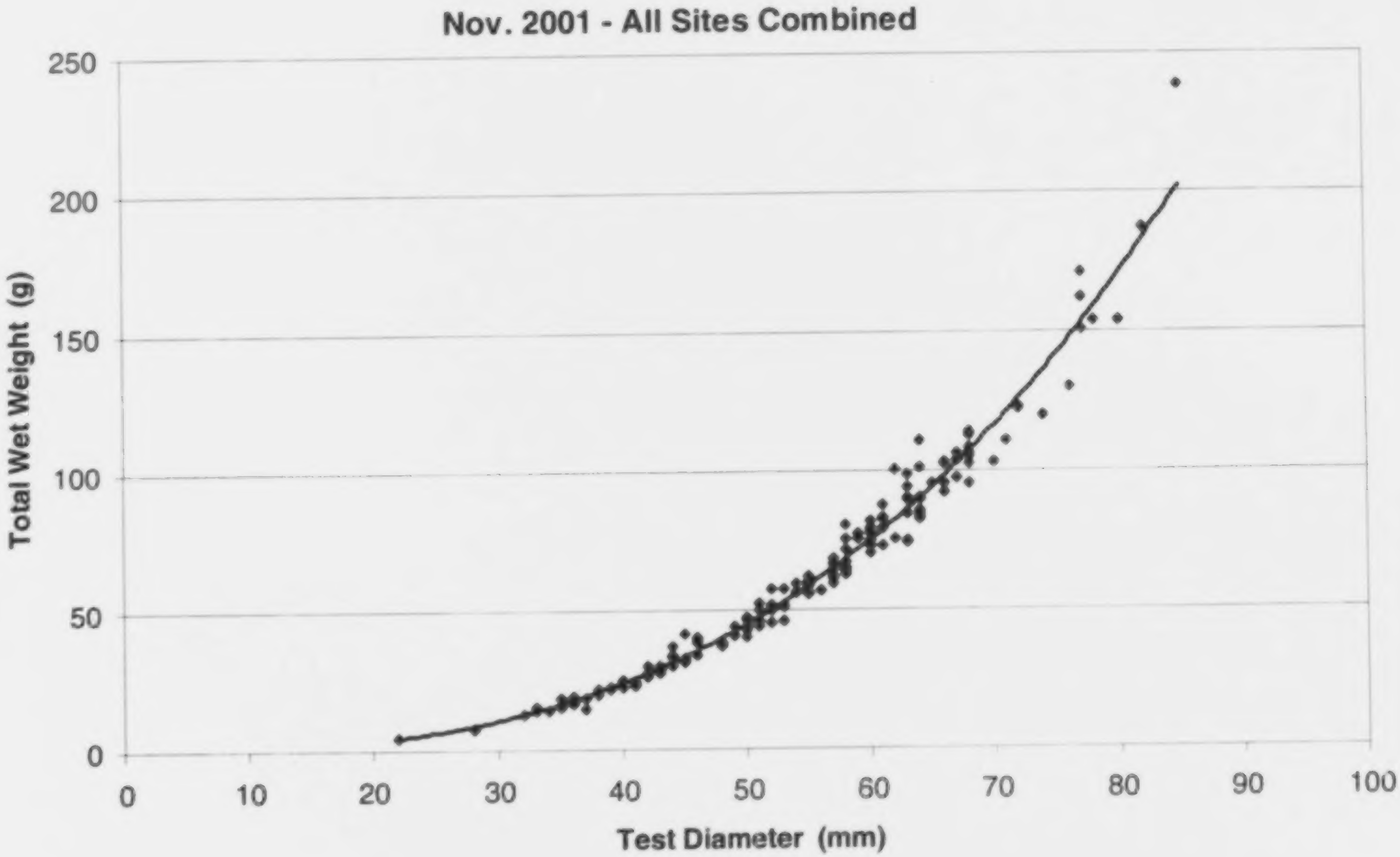
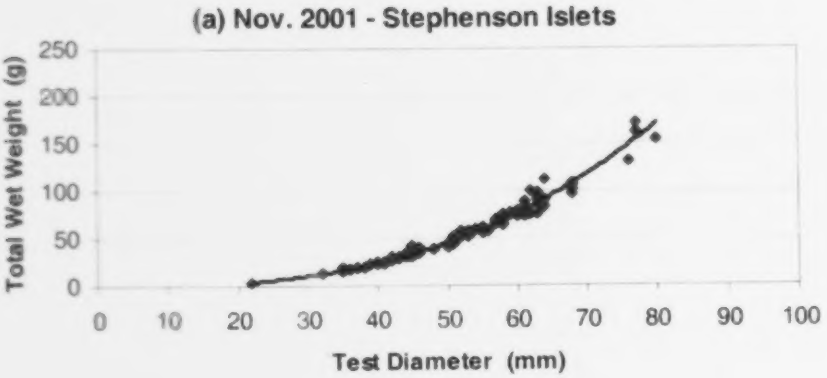
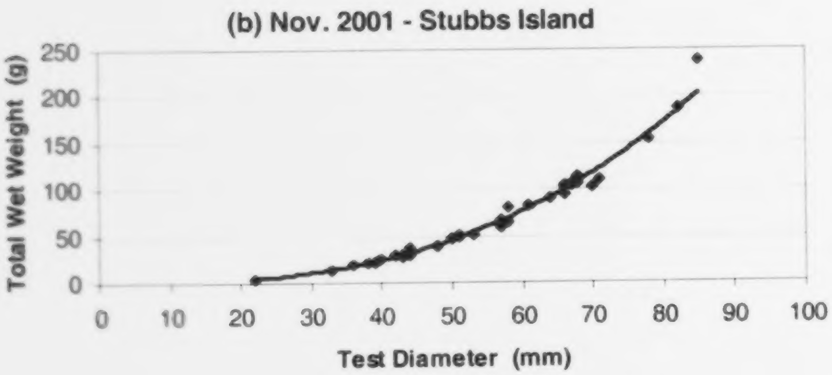


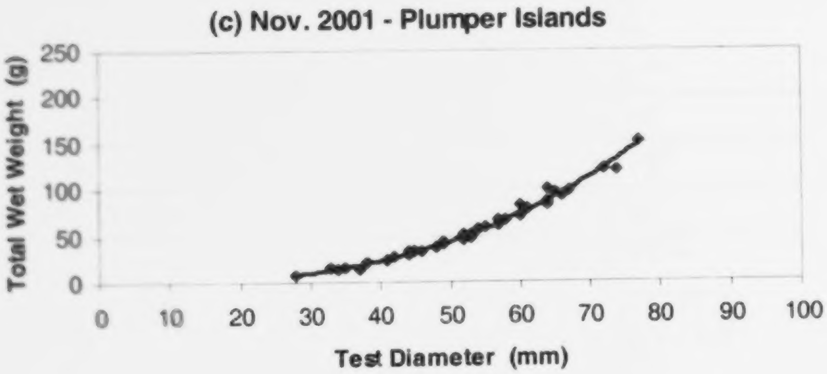
Fig. 35. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in November, 2001, for all sites combined: TOTAL WET WEIGHT (g) = $0.0007(\mathrm{TD}^{2.8343})$, $R^2 = 0.9878$, n=166.



(a) Nov. 2001 - Stephenson Islets



(b) Nov. 2001 - Stubbs Island



(c) Nov. 2001 - Plumper Islands

Fig. 36. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in November, 2001 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = 0.0007($\text{TD}^{2.8337}$), $R^2 = 0.9842$, n=87);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = 0.0008($\text{TD}^{2.8079}$), $R^2 = 0.9929$, n=37);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = 0.0006($\text{TD}^{2.8510}$), $R^2 = 0.9906$, n=42).

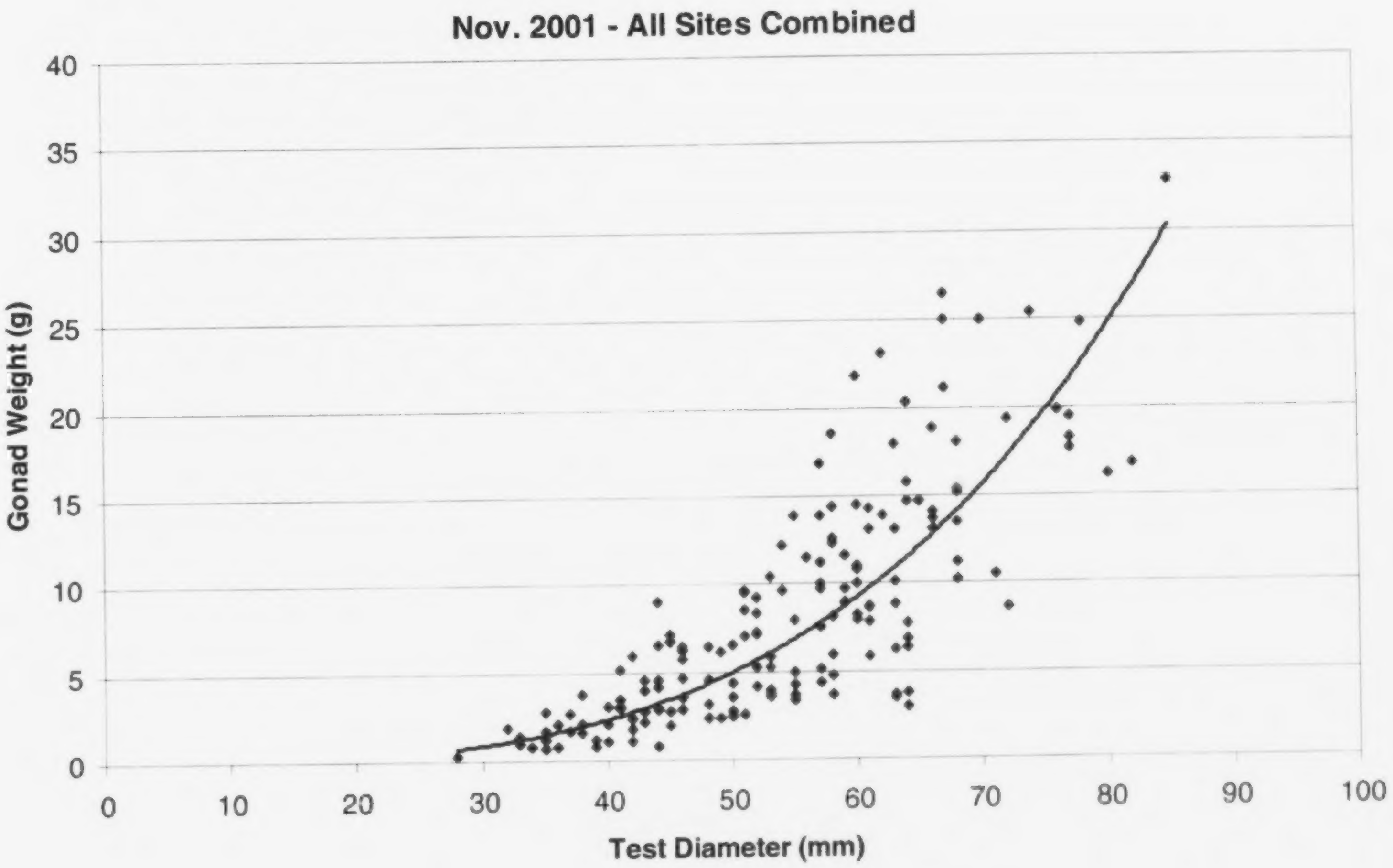
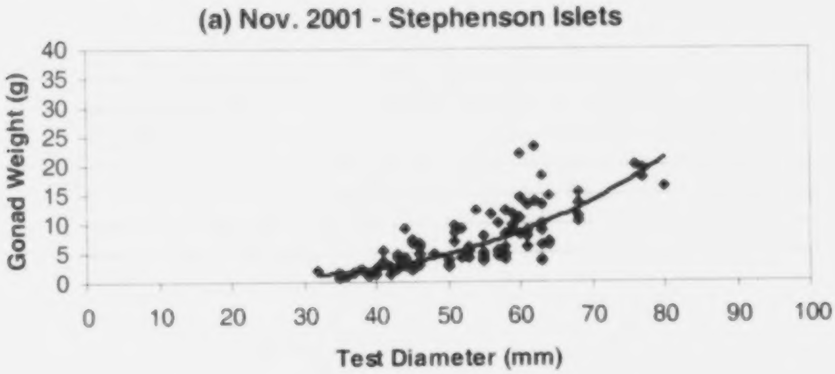
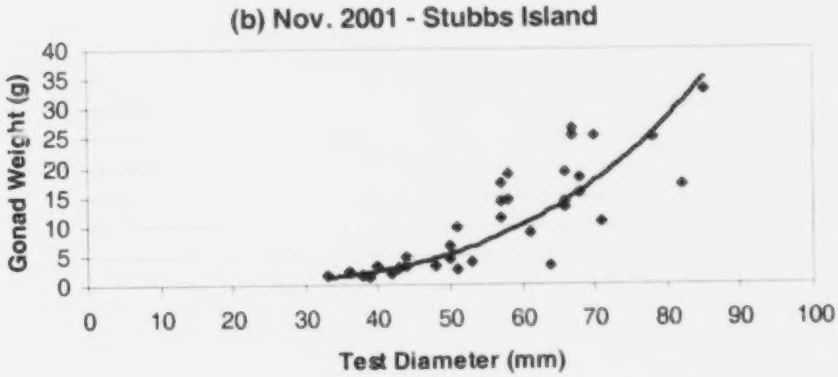


Fig. 37. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in November, 2001, calculated from all sites combined: GONAD WEIGHT (g) = 8×10^{-6}(TD$^{3.3981}$); $R^2 = 0.7065$, n = 165.





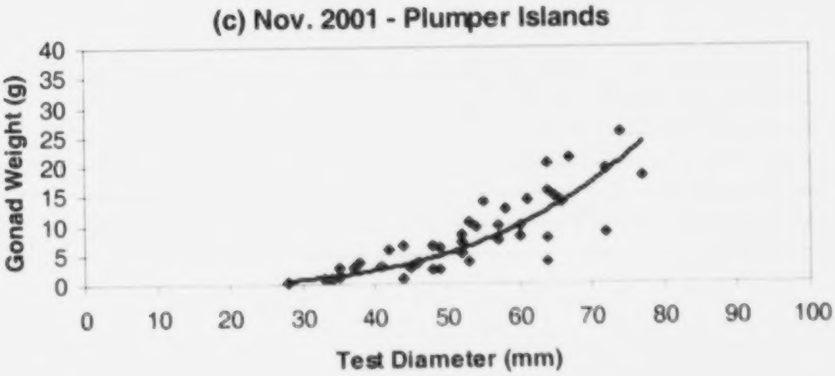


Fig. 38. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in November, 2001 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 2×10^{-5} ($\mathrm{TD}^{3.1639}$), $R^2 = 0.6349$, n=87);
(b) Stubbs Island (GONAD WEIGHT (g) = 4×10^{-6} ($\mathrm{TD}^{3.5782}$), $R^2 = 0.7815$, n=36);
(c) Plumper Islands (GONAD WEIGHT (g) = 5×10^{-6} ($\mathrm{TD}^{3.5517}$), $R^2 = 0.7432$, n=42).

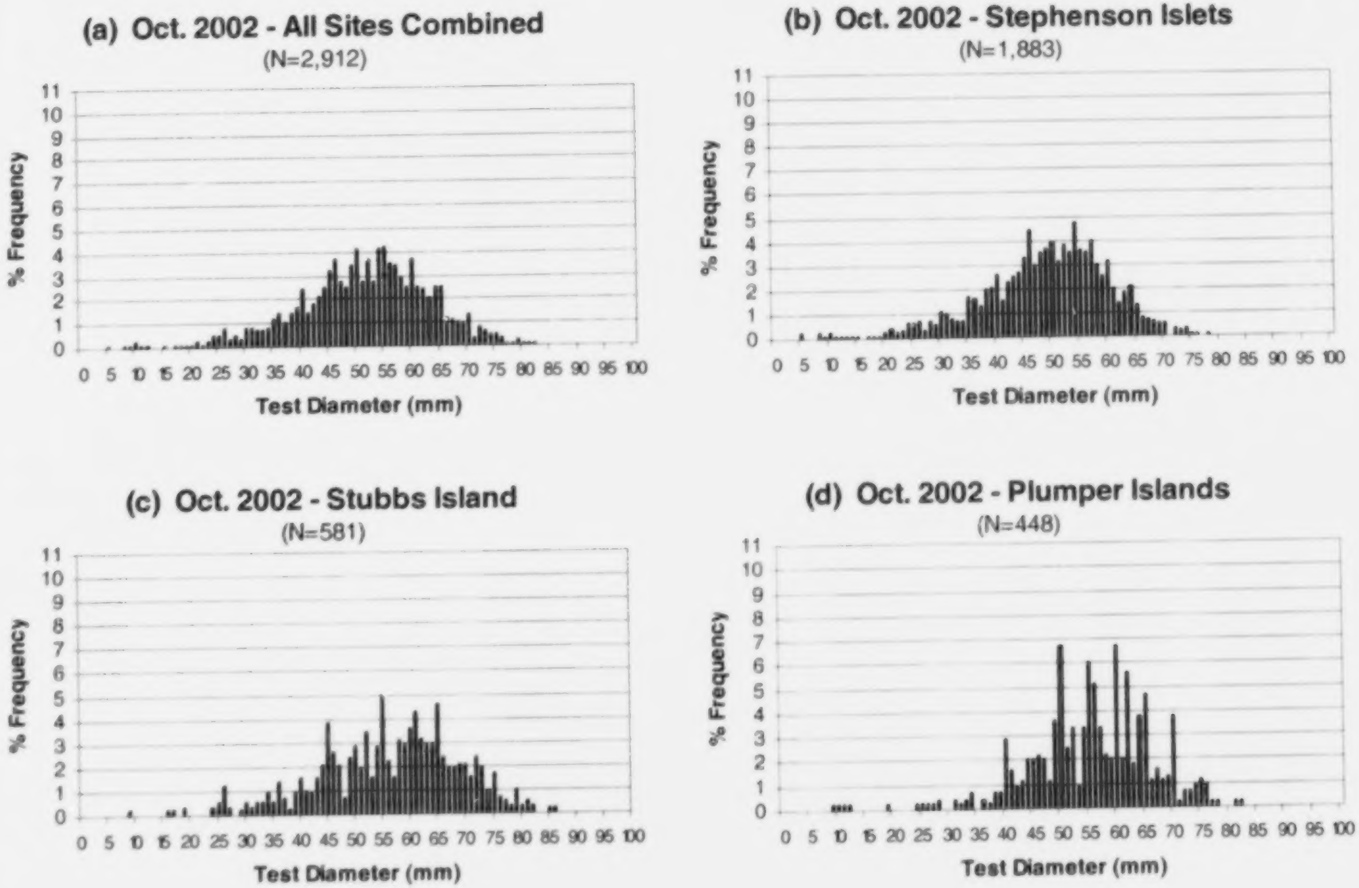


Fig. 39. Size (test diameter in millimeters) distribution of green sea urchins collected in October, 2002 from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note the fishery minimum size limit is 55 mm.

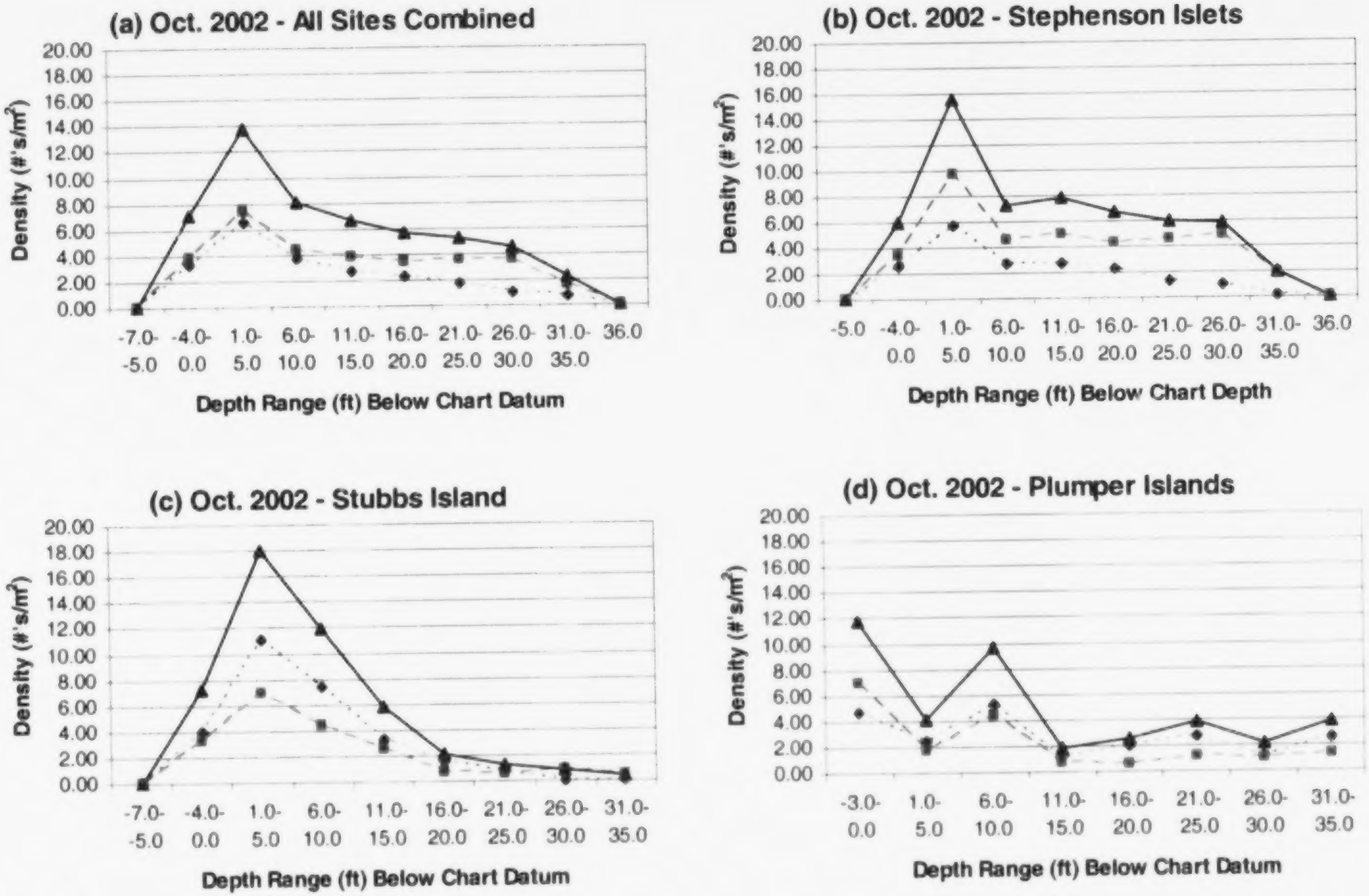
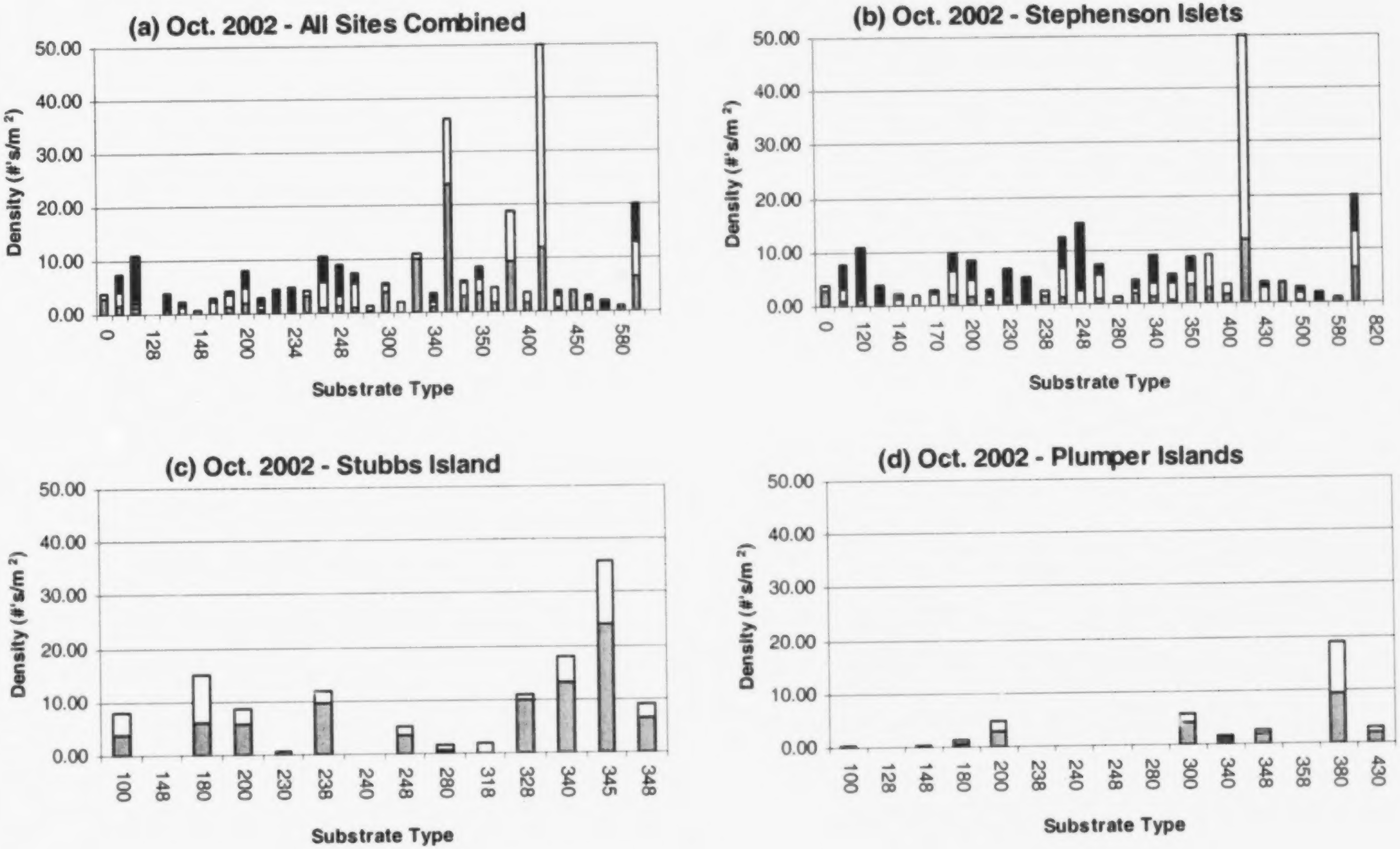


Fig. 40. October, 2002 mean densities (number per square meter) of green sea urchins of all sizes (total = triangles), legal size (diamonds), and sublegal size (squares) by depth range (feet) below Chart Datum from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. Note that the unmeasured urchins ("unknowns") have been proportioned into the legal and sublegal density estimates by using the ratios from measured data, then adding the original legal and sublegal values, and assigning a zero value to the unknowns. Note that the density scale is consistent for all of the "density by depth" charts between all five surveys.


(a) Oct. 2002 - All Sites Combined

(b) Oct. 2002 - Stephenson Islets

(c) Oct. 2002 - Stubbs Island

(d) Oct. 2002 - Plumper Islands

Fig. 41. October, 2002 mean densities (number per square meter) of green sea urchins of legal size (grey), sublegal (white), and unknown size (black), by substrate type from: (a) all sites combined; (b) Stephenson Islets; (c) Stubbs Island; and (d) Plumper Islands. See Tables 33a-d for the keys to the substrate codes. Unidentified substrates not displayed. Note that the density scale is consistent for all of the "density by substrate" charts between all five surveys throughout the report.

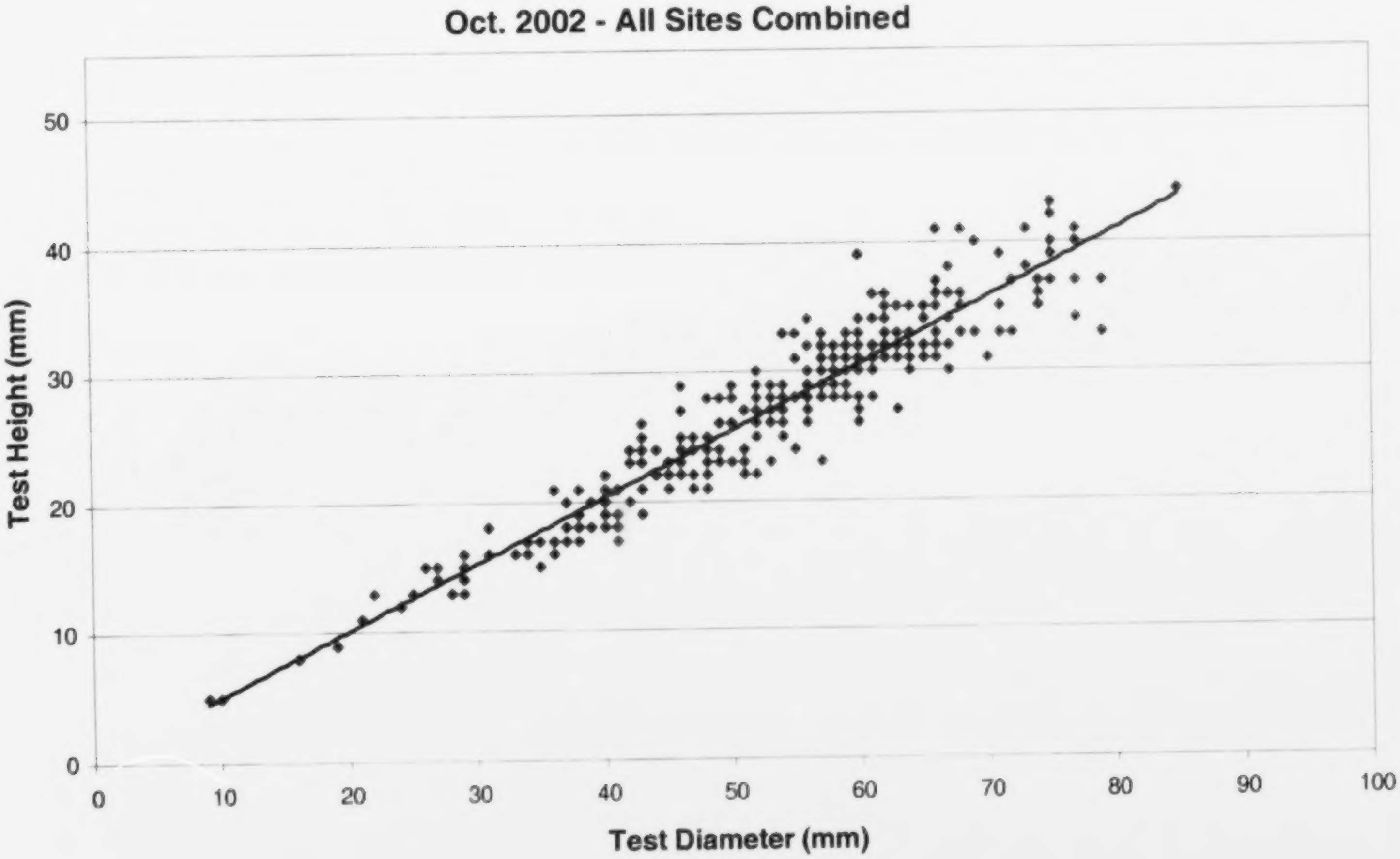
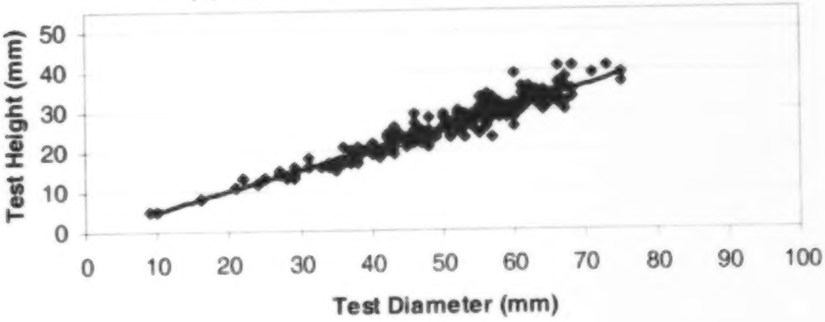
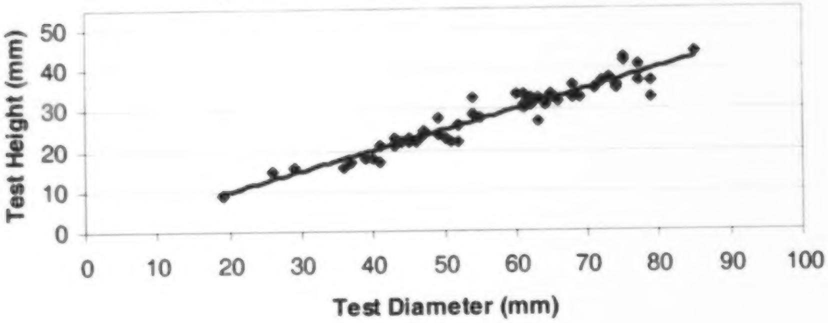


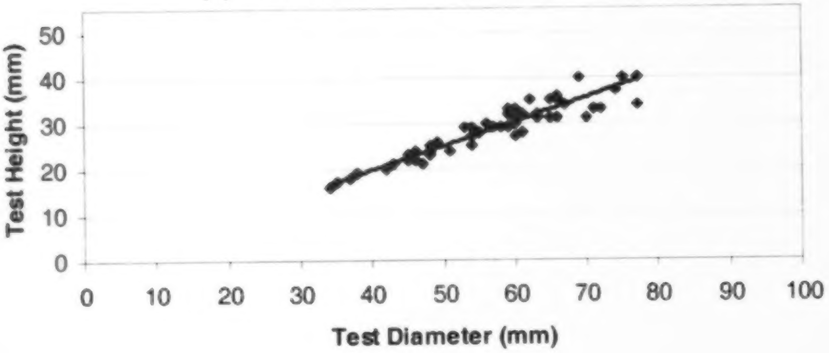
Fig. 42. Relationship between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) in October, 2002, for all sites combined: TEST HEIGHT (mm) = $0.4956(\mathrm{TD}^{1.0073})$, $R^2 = 0.9328$, n=320.



(a) Oct. 2002 - Stephenson Islets



(b) Oct. 2002 - Stubbs Island



(c) Oct. 2002 - Plumper Islands

Fig. 43. Relationships between green sea urchin test diameter (TD, in millimeters) and test height (millimeters) calculated in October, 2002 for:
(a) Stephenson Islets (TEST HEIGHT (mm) = $0.4889(\mathrm{TD}^{1.0130})$, $R^2 = 0.9378$, n=209);
(b) Stubbs Island (TEST HEIGHT (mm) = $0.4812(\mathrm{TD}^{1.0106})$, $R^2 = 0.9233$, n=58);
(c) Plumper Islands (TEST HEIGHT (mm) = $0.4154(\mathrm{TD}^{1.0475})$, $R^2 = 0.9104$, n=53).

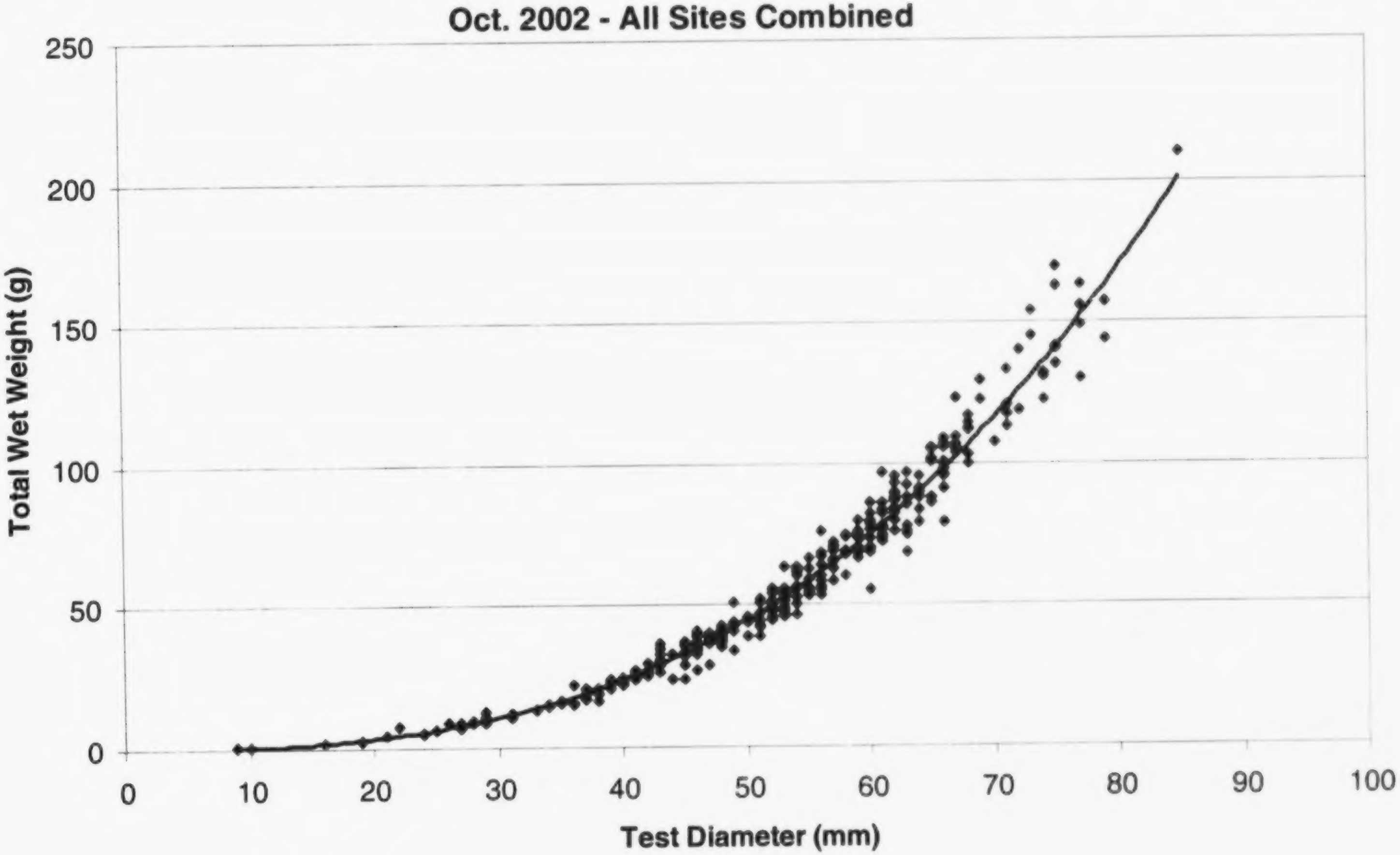
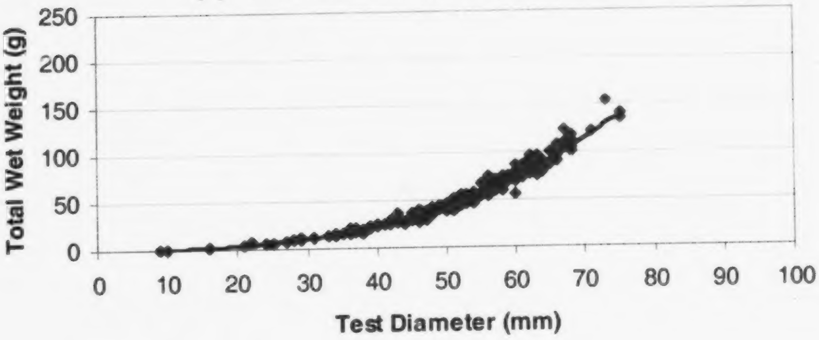
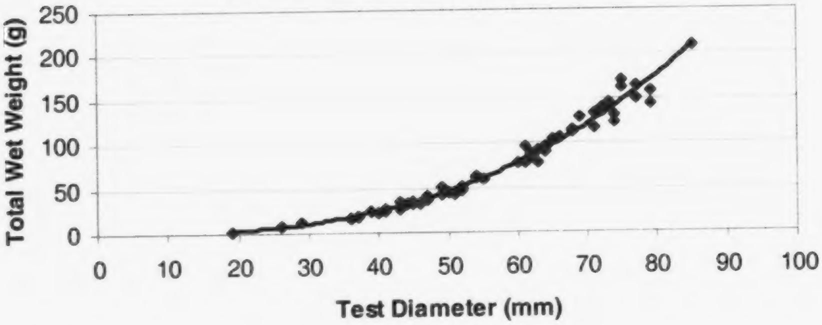


Fig. 44. Relationship between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) in October, 2002, for all sites combined: TOTAL WET WEIGHT (g) = $0.0007(\mathrm{TD}^{2.8242})$, $R^2 = 0.9870$, n=320.

(a) Oct. 2002 - Stephenson Islets



(b) Oct. 2002 - Stubbs Island



(c) Oct. 2002 - Plumper Islands

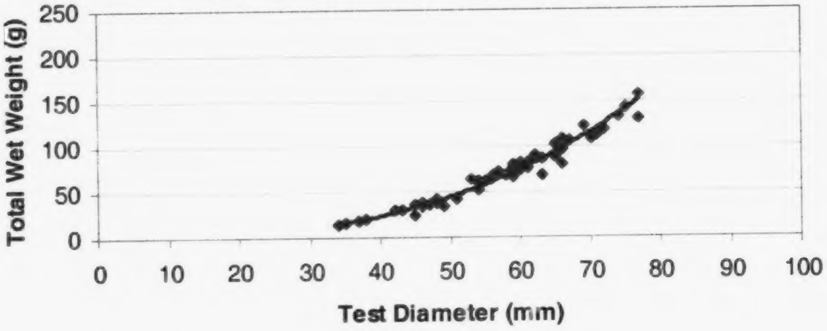


Fig. 45. Relationships between green sea urchin test diameter (TD, in millimeters) and total wet weight (grams) calculated in October, 2002 for:
(a) Stephenson Islets (TOTAL WET WEIGHT (g) = 0.0007($TD^{2.8108}$), $R^2 = 0.9880$, n=209);
(b) Stubbs Island (TOTAL WET WEIGHT (g) = 0.0007($TD^{2.8367}$), $R^2 = 0.9888$, n=58);
(c) Plumper Islands (TOTAL WET WEIGHT (g) = 0.0007($TD^{2.8345}$), $R^2 = 0.9717$, n=53).

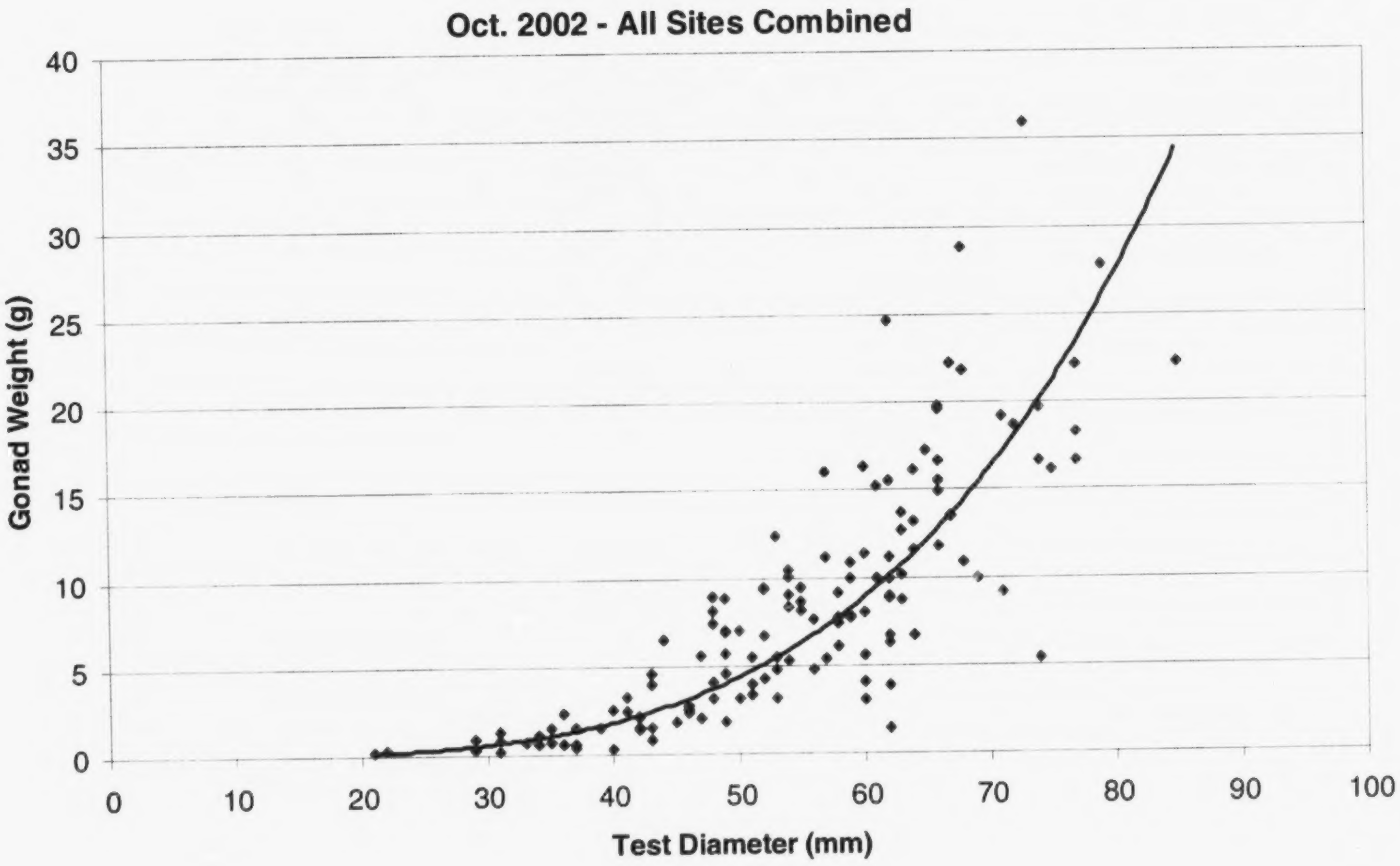
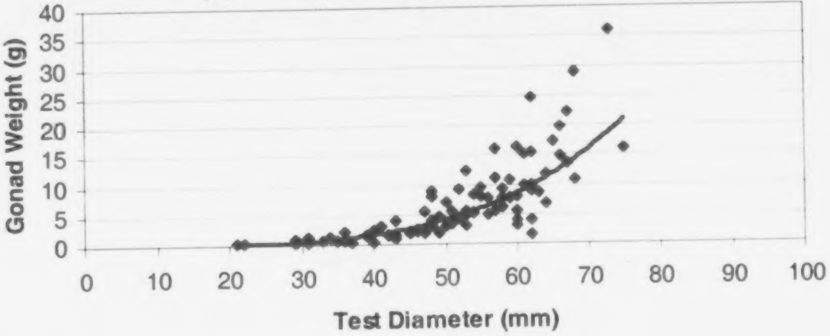
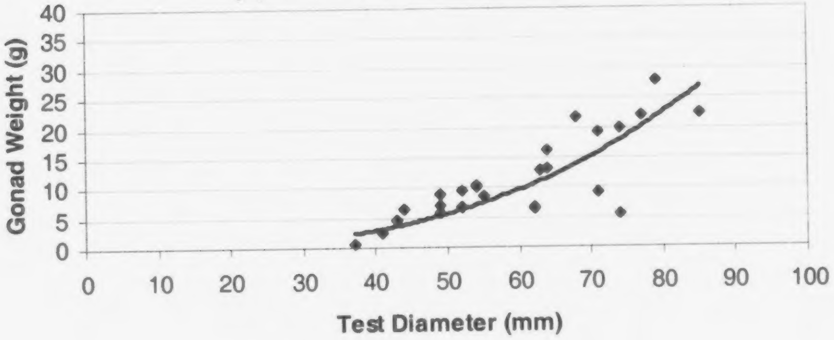


Fig. 46. Relationship between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) in October, 2002, calculated from all sites combined: GONAD WEIGHT (g) = 1 x $10^{-6}(\text{TD}^{3.8933})$; $R^2 = 0.7822$, n = 135.

(a) Oct. 2002 - Stephenson Islets



(b) Oct. 2002 - Stubbs Island



(c) Oct. 2002 - Plumper Islands

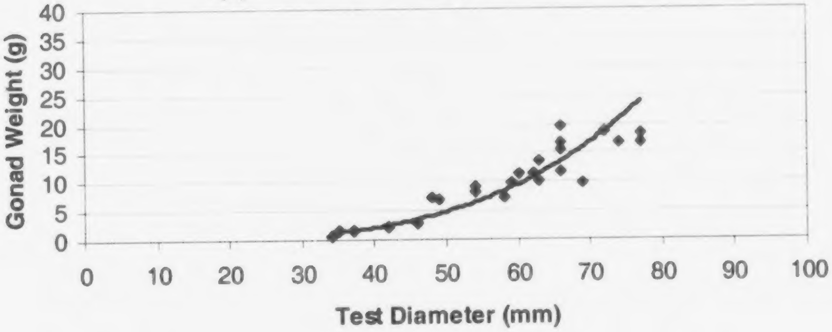


Fig. 47. Relationships between green sea urchin test diameter (TD, in millimeters) and gonad weight (grams) calculated in October, 2002 for:
(a) Stephenson Islets (GONAD WEIGHT (g) = 6×10^{-7} ($\mathrm{TD}^{4.0223}$), $R^2 = 0.7702$, n=86);
(b) Stubbs Island (GONAD WEIGHT (g) = 6×10^{-5} ($\mathrm{TD}^{2.9292}$), $R^2 = 0.6403$, n=25);
(c) Plumper Islands (GONAD WEIGHT (g) = 3×10^{-6} ($\mathrm{TD}^{3.6911}$), $R^2 = 0.8988$, n=24).